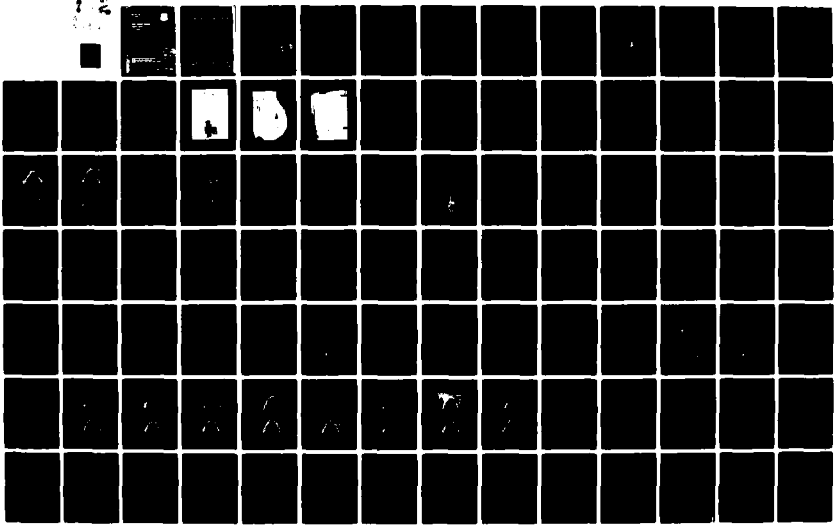
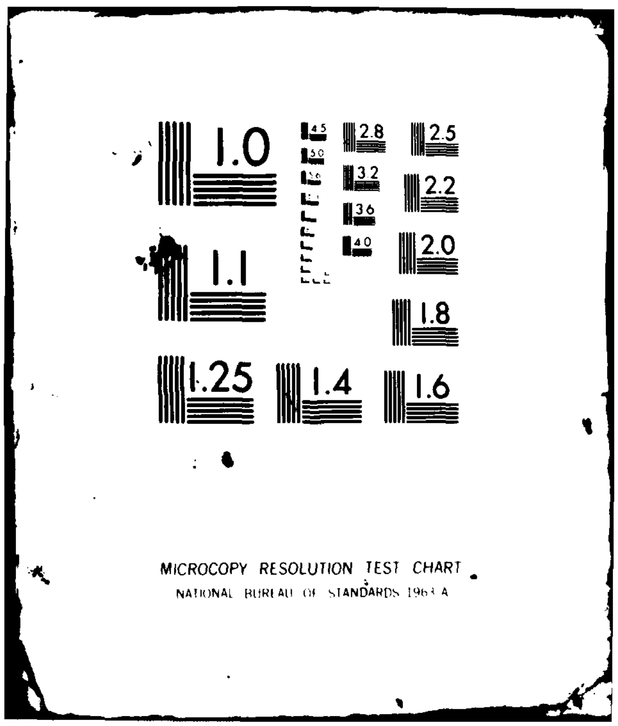
AD-A113 191 HARRIS CORP MELBOURNE FL GOVERNMENT COMMUNICATION SY--ETC F/G 20/14

TENT SHAPED PHASED ARRAY TESTS.(U)

JAN 82 C A CHUANG F19628-79-C-0173

UNCLASSIFIED RADC-TR-81-281 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER RADC-TR-81-281	2. GOVT ACCESSION NO. AD-A113 191	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TENT SHAPED PHASED ARRAY TESTS		5. TYPE OF REPORT & PERIOD COVERED Final Technical Report
		6. PERFORMING ORG. REPORT NUMBER N/A
7. AUTHOR(s) C. A. Chuang		8. CONTRACT OR GRANT NUMBER(s) F19628-79-C-0173
9. PERFORMING ORGANIZATION NAME AND ADDRESS HARRIS CORPORATION Government Communications Systems Division P. O. Box 37, Melbourne FL 32901		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62702F 46001445
11. CONTROLLING OFFICE NAME AND ADDRESS Deputy for Electronic Technology (RADC/EEAA) Hanscom AFB MA 01731		12. REPORT DATE January 1982
		13. NUMBER OF PAGES 106
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Same		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: John McIlvenna (RADC/EEAA)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aircraft Arrays
Phased Arrays
Satellite Communications Antenna

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This final report presents experimental results for a breadboard phased array. The breadboard consists of 24 square waveguide and septum polarizer elements, diode phase shifters, a feed network, and a microprocessor array controller. The breadboard is a part of a tent-shaped phased array SHF aircraft antenna for satellite communications. The tent array consists of four planar phased arrays and has a low profile streamlined configuration. It provides electrical scanning over a hemisphere and is

cont

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

cont

capable of high power transmission. The design of the array is a trade-off of the key parameters including gain, coverage, aerodynamic impact, high power transmission, and array packaging. A study was performed to derive an optimum array configuration. Design considerations and study results were presented in the Interim Report. Experimental testing of the breadboard reported herein verified the concept of the tent-shaped phased array. Additional breadboard tests and further studies are recommended. The designs of 20dB and 30dB gain tent arrays are included.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1.0 INTRODUCTION

There is an interest in the design of an effective low profile, high gain, SHF aircraft antenna for Satellite Communications to provide coverage over the entire upper hemisphere. The excessive air drag produced by the large radomes of existing SHF aircraft terminals using parabolic antennas makes this antenna configuration unattractive for many applications, especially for high performance aircraft. Low profile antennas such as microstrip antenna arrays or an electro-mechanical steered phased array are realizable candidate antennas. However, the arrays cannot provide efficient coverage near the nose and tail regions of the aircraft due to physical and geometrical limitations.

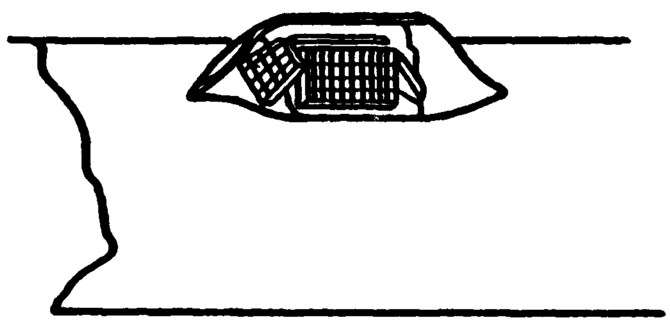
The candidate antenna investigated in this study is a tent shaped phased array* which consists of four planar arrays arranged in a streamlined configuration and packed inside the tent structure as shown in Figure 1. The tent array is low profile and provides an electronically steerable beam for hemispherical coverage. The antenna is capable of high power transmission and provides an adequate gain coverage near the horizon. It is a compromise solution between gain coverage and aerodynamic impact.

A study was performed by Harris Government Communications Systems Division to design a tent shaped phased array to meet the required antenna specifications. The design of an optimum array configuration and the selection of array components depend on effective trade-offs among the design parameters such as gain, coverage, aerodynamic impact, transmit power, and array packaging. The components of the selected array configuration include square waveguide elements, septum polarizers, ferrite phase shifters for transmit and diode phase shifters for receive, a compact feed network, and a microprocessor array controller. The detailed design considerations, array designs, and descriptions of array components were presented in the Interim Report of the program. A 4 x 6 breadboard array was built and tested to demonstrate the feasibility of the tent array design.

*Mailloux, R. J. and Marvoides, W. G., "Hemispherical Coverage of Four-Faced Aircraft Arrays", RADC-TR-79-176, May 1979.

In the following, a brief discussion of the tent array design and its components is presented. The breadboard hardware and experimental set-ups for breadboard testing are described. The experimental results are summarized. The designs of 20dB and 30dB gain tent arrays are given.

TENT SHAPED PHASED ARRAY CONFIGURATION



11730-2

FIGURE 1

2.0 TENT SHAPED PHASED ARRAY

A detailed study was performed to design a Tent Shaped Phased Array to meet the antenna specifications shown in Table 1. The design of an optimum array configuration and the selection of array components rely on effective trade-offs among the key design parameters. These parameters include coverage, gain, aerodynamics, array packaging, and high transmit power. The Tent Shaped array design, as the result of the study, consists of four planar phased arrays arranged in the desired configuration. Each face of the array consists of square waveguide elements, septum polarizers, ferrite phase shifters for transmit and diode phase shifters for receive, and a compact feed network. A microprocessor is used to provide the function of beam steering and phase correction. The study results and the detailed description of the array and components were reported in the Interim Report of the program. A brief review of basic characteristics of the components is given in the following.

2.1 Element Module. The element module of the arrays contains the open-ended square waveguide aperture, a septum polarizer, and phase shifters for transmit and receive. The element module of this wide angle scan array is dielectrically loaded to allow the elements to be closely spaced for grating lobe elimination. The elements are arranged in a triangular grid to minimize the number of needed antenna elements and to optimize axial ratio performance of the array. The septum polarizer is considered an integral part of the square waveguide element and was selected to permit dual polarization operation of the array. Ferrite phase shifters were selected for the transmit operation, and 4-bit diode phase shifters for the receiving function. The ferrite phase shifters have the advantage of high power handling capability which is necessary for tent array transmit operation. The diode phase shifters have the advantages of lower cost and reduced size and weight, and are therefore suitable for the tent array receive function. A 4-bit phase shifter was adopted after consideration of sidelobe level generated by the phase quantization error.

2.2 Feed Network. The key design considerations for the feed network

TABLE 1. TENT ARRAY SPECIFICATIONS

Frequency:	7.25 to 7.75 GHz, receive 7.90 to 8.4 GHz, transmit
Polarization:	RHCP, transmit LHCP, receive
Axial Ratio:	3 dB to within 10° of horizon
Gain:	20 dB except 30° half cone at nose and tail where 18 dB is acceptable.
Sidelobes:	-20 dB in the azimuth plane -12 dB in the elevation plane
VSWR:	< 2:1
Power:	3 kW CW, goal
Physical Requirements:	- Maximum tent size: 36" length, 8" height - Conform to C-135 type aircraft - 5" radius maximum aircraft hole

for the tent array include power handling capability, low loss, and compactness for aerodynamic operation. One conceptual design of a nonconventional feed network as shown in Figure 13 of the Interim Report, employs a common waveguide to feed elements of each row through coupling holes or slots. This design represents a very compact low loss waveguide system for the feed network. However, the control of mutual coupling among the amplitude coupling holes in the common waveguide and the wideband impedance matching require special treatment. An alternate design, which uses septum type power dividers for power distribution and amplitude tapering, and uses step transformers for impedance matching, represents a simple and practical feed network for immediate applications. It was selected as the baseline design and for breadboard testing.

The baseline feed network, as shown in Figure 2 and illustrated in Figure 17 of the Interim Report, consists of three major parts; namely, the elevation power divider (combiner), the azimuth power divider (combiner), and the waveguide transformer. The elevation power divider consists of binary power dividers which provide uniform power distribution in the elevation plane. The binary power dividers are connected to azimuth power dividers which divide the power into the elements on the row with proper amplitude taper. The connection is accomplished through the use of H-plane tees. The azimuth power dividers feed the element modules through the step waveguide transformers which provide the functions of impedance matching.

2.3 Array Controller. A microprocessor was selected for the array controller. It commands the array phase shifters for proper phase setting, and is also capable of performing the functions of array aperture switching logic, coordinate transformation, feeding phase error correction in frequency, and calculation of needed phase shifting based on scan angle, frequency, and element locations.

3.0 TENT SHAPED ARRAY BREADBOARD

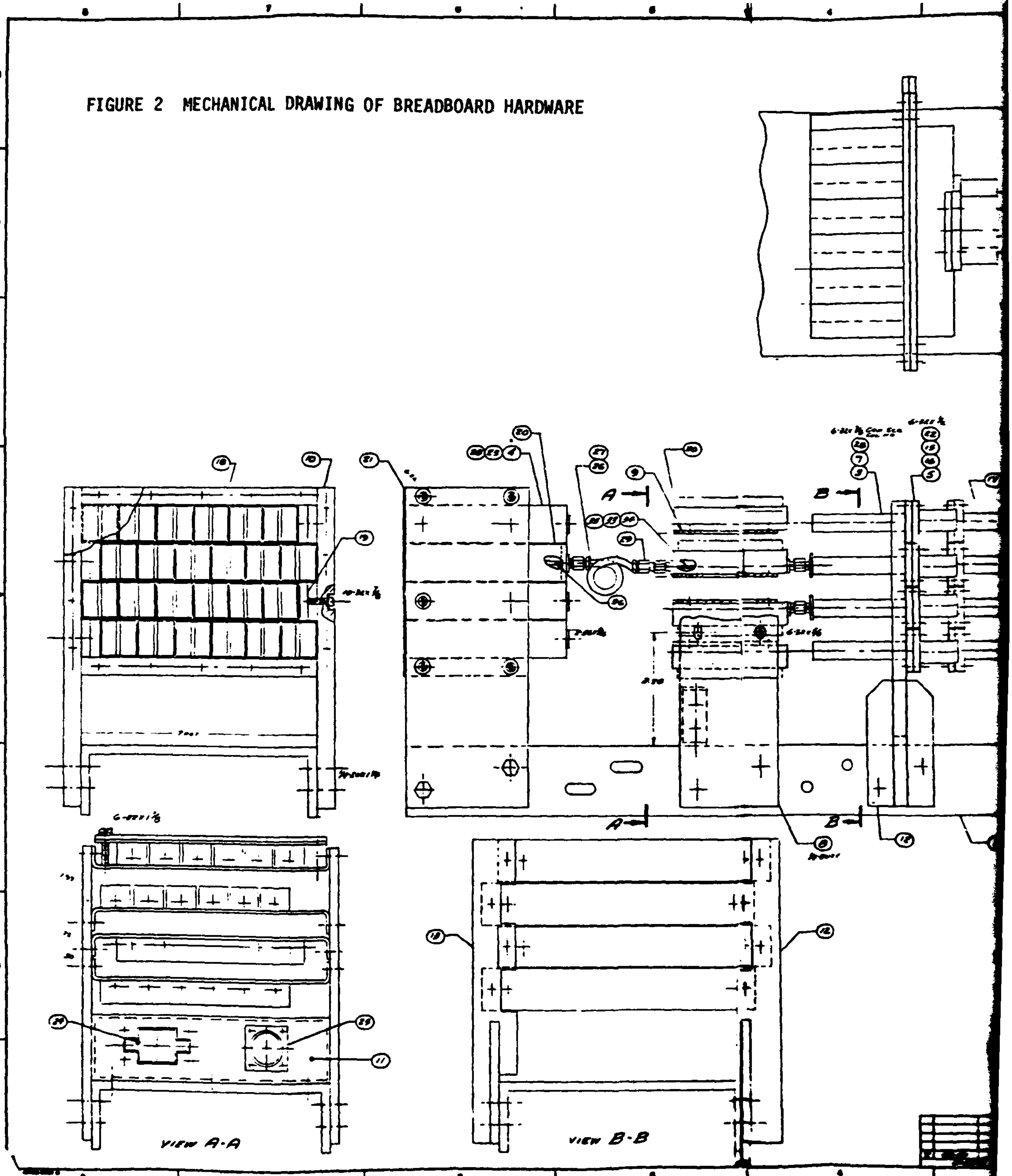
A 4 x 6 breadboard array was designed, fabricated and tested to verify the concept and demonstrate the feasibility of the tent array design. The breadboard is a part of the end face of the tent array. It consists of 24 square waveguide elements including the septum polarizer, 24 3-bit diode phase shifters, a waveguide feed network, and a microprocessor. The components were first tested in the laboratory for performance characterization, and then assembled as an integrated array for electronic scanning and antenna pattern measurements. The array was tested in the receive mode with transmit ports of the elements properly loaded. The description of breadboard hardware and array testing set-up is presented in this section.

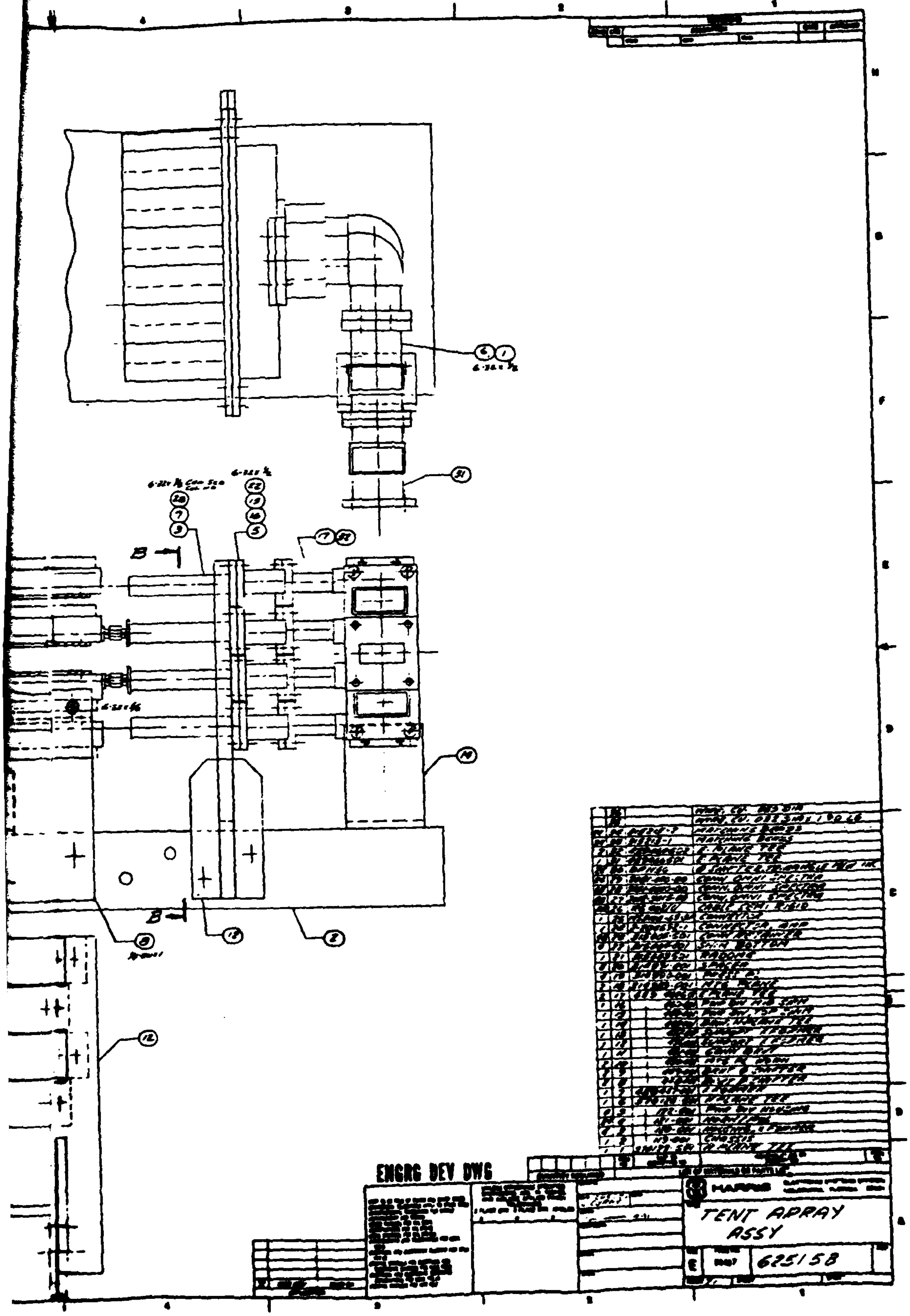
3.1 Breadboard Hardware. The key objective of the breadboard hardware is to demonstrate the performance characteristics of the components and to verify the concept of the tent array. Mechanical structure of the hardware was not fully optimized for airborne packaging applications. It was fabricated to accommodate breadboarding, laboratory tuning, and range testing. Nevertheless, the basic principle of the tent array is illustrated, and the performance of the full size tent array can be predicted.

The components of the breadboard hardware can be divided into two major parts; namely, the array assembly and the array controller. As is illustrated in the mechanical drawing of Figure 2, the array assembly consists of waveguide elements, phase compensators, phase shifters, the azimuth power combiner including waveguide transformer, the elevation power combiner, and the holding fixture. The phase compensators utilize semi-rigid cables to compensate the phase differentials among the elements due to azimuth power combining and manufacturing offsets of phase shifters. The components of the array assembly are connected through the use of SMA connectors, adaptors, and transitions, which contributed significantly to the overall depth of the breadboard hardware. An overview of the breadboard hardware is given in Figure 3. A photo of the array assembly is presented in Figure 4. A close look at the array aperture is shown in Figure 5.

The array controller consists of a Northstar microprocessor (Z80),

FIGURE 2 MECHANICAL DRAWING OF BREADBOARD HARDWARE





2

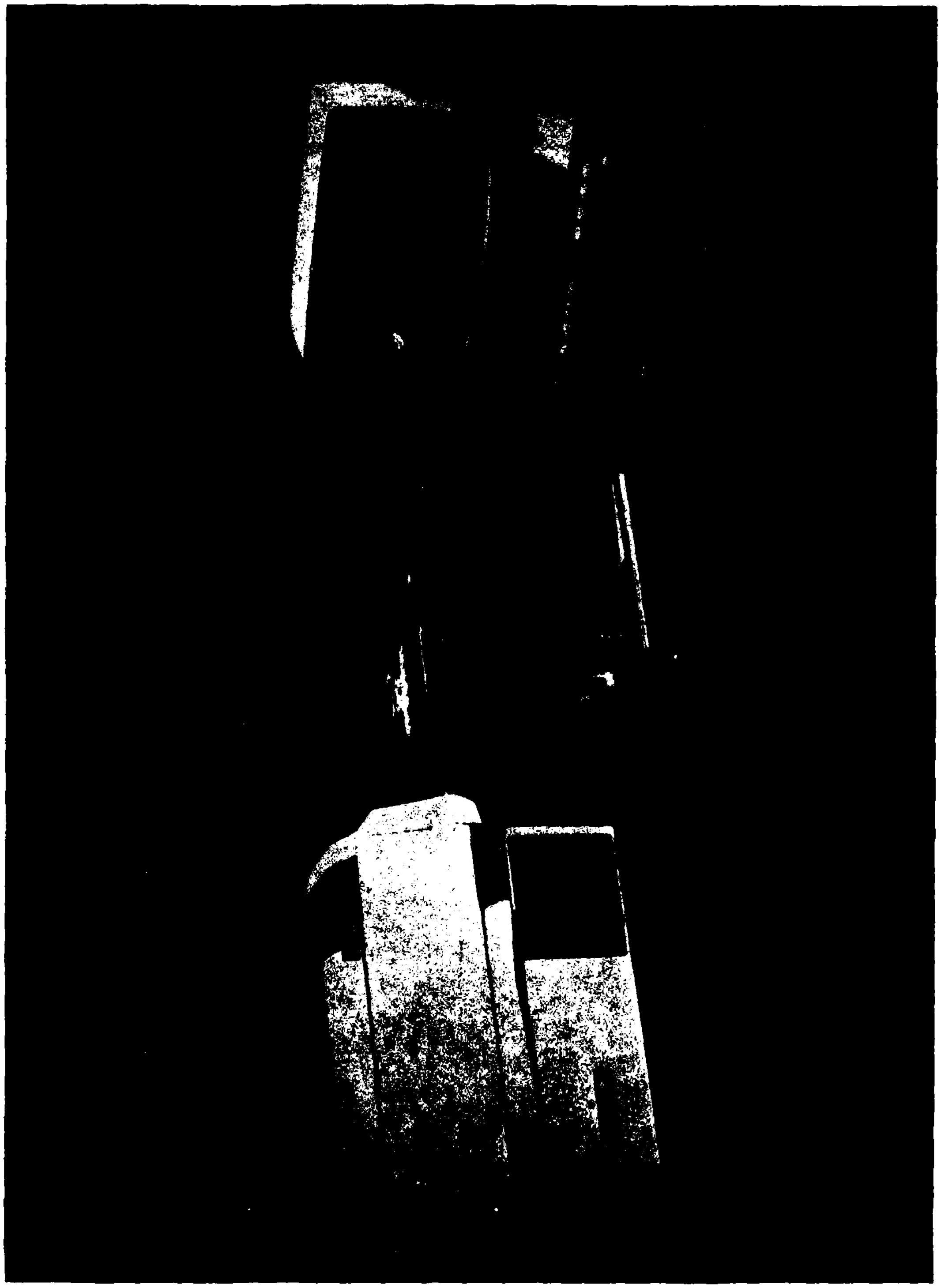


FIGURE 3 THE TENT ARRAY BREADBOARD HARDWARE

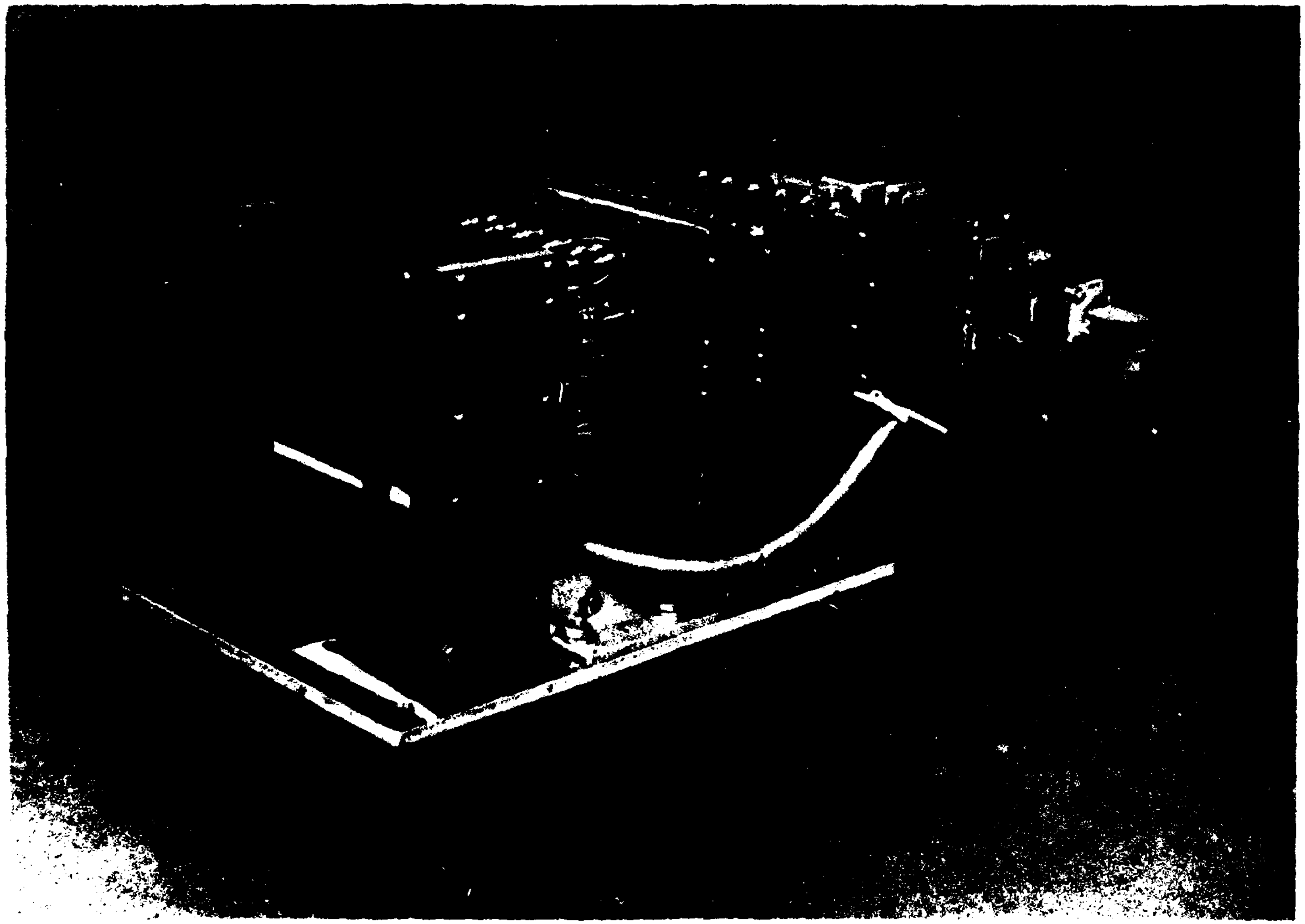


FIGURE 4 A PHOTO OF THE TENT ARRAY BREADBOARD HARDWARE

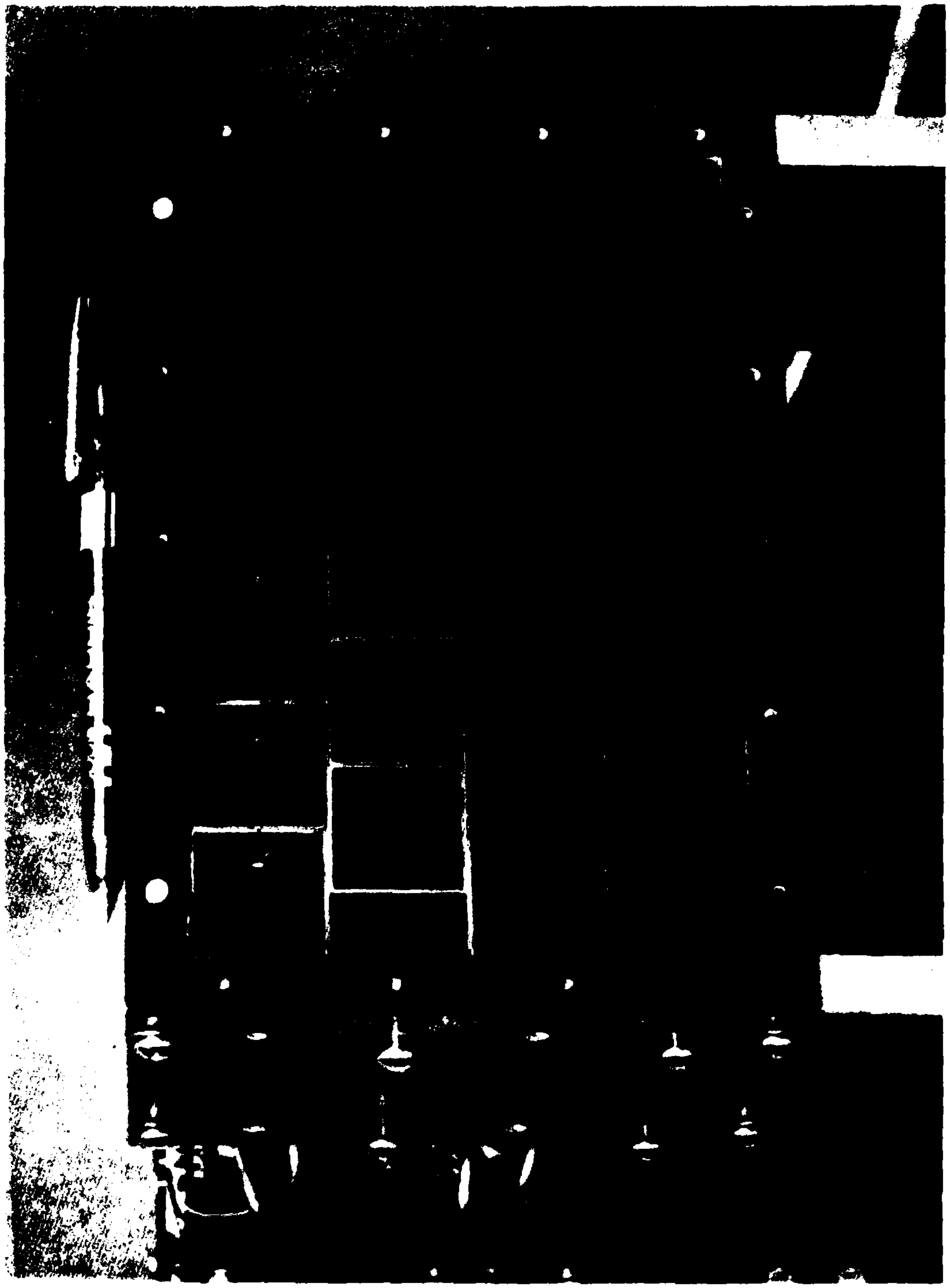


FIGURE 5 THE TENT ARRAY BREADBOARD APERTURE

a line printer, and a terminal display. The interface between the array controller and the array assembly is accomplished through the cable transmission of digital signals from the computer to the phase shifter drivers for phase shifter command. The detail of the software design approach of the controller is documented in the Progressive Project Document (PPD), and is attached in Appendix A. The PPD is a Harris internal control document which is required for any documented software produced by Harris Engineering. It describes the structure, block diagram, background, and programming details of the subject software.

3.2 Experimental Set-Ups. Laboratory test is a part of the process in the design, fabrication and tuning of the array components. Typical laboratory test set-ups are shown in Figures 6 and 7. These test set-ups were used to measure electrical parameters of the integrated array, partially integrated array and breadboard components such as antenna elements, phase shifters, and feed network. A similar set-up was also used to measure the axial ratio performance of the individual septum polarizers. Phase differentials among the individual ports of the partially integrated array including feeding network and phase shifters were measured through the frequency bandwidth of interest (7.25 to 7.75 GHz). Proper semi-rigid cables were selected to connect the output ports of the partially integrated array to the antenna elements, and to compensate for the phase differentials.

A special test set-up as shown in Figure 8 was established to measure the performance of each 3-bit phase shifter manufactured by Triangle Microwave Corporation. The performance characteristics of a typical acceptable phase shifter unit are presented in Table 2.

The integrated breadboard array was tested in a small anechoic chamber. Antenna patterns, axial ratios, and antenna gain were measured. The experimental set-up of the range test is depicted in Figure 9. The measurement results are summarized in the next section.

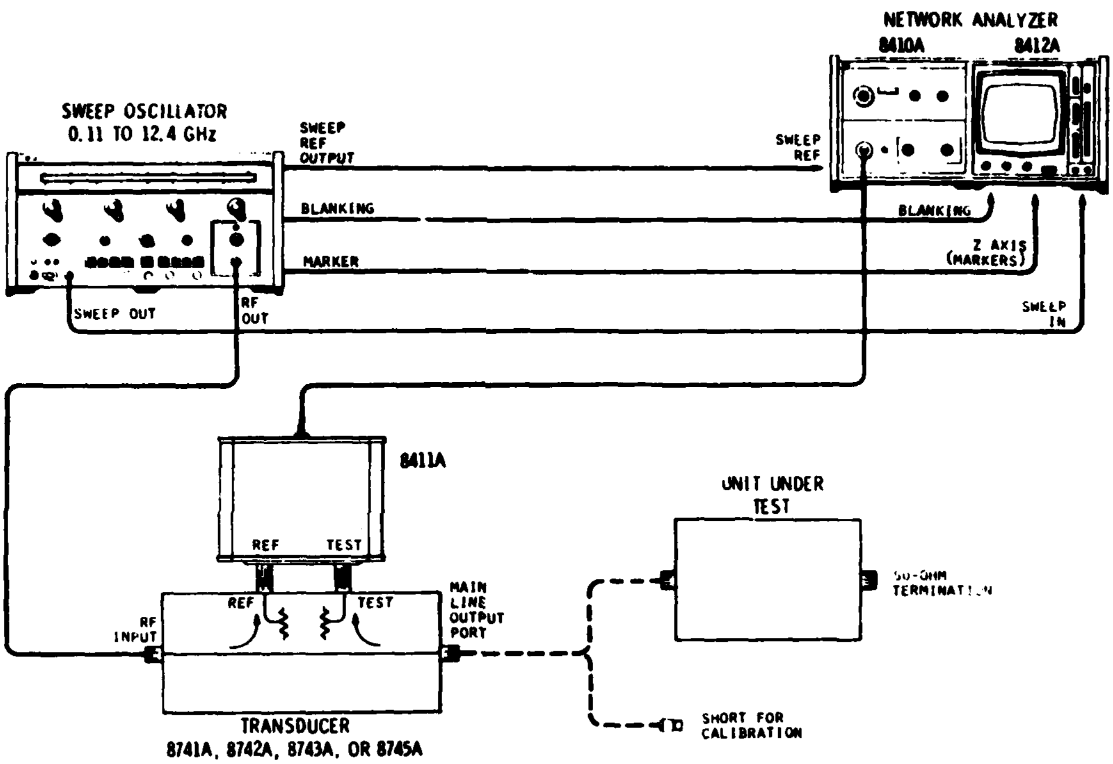


FIGURE 6 TYPICAL REFLECTION TEST SETUP

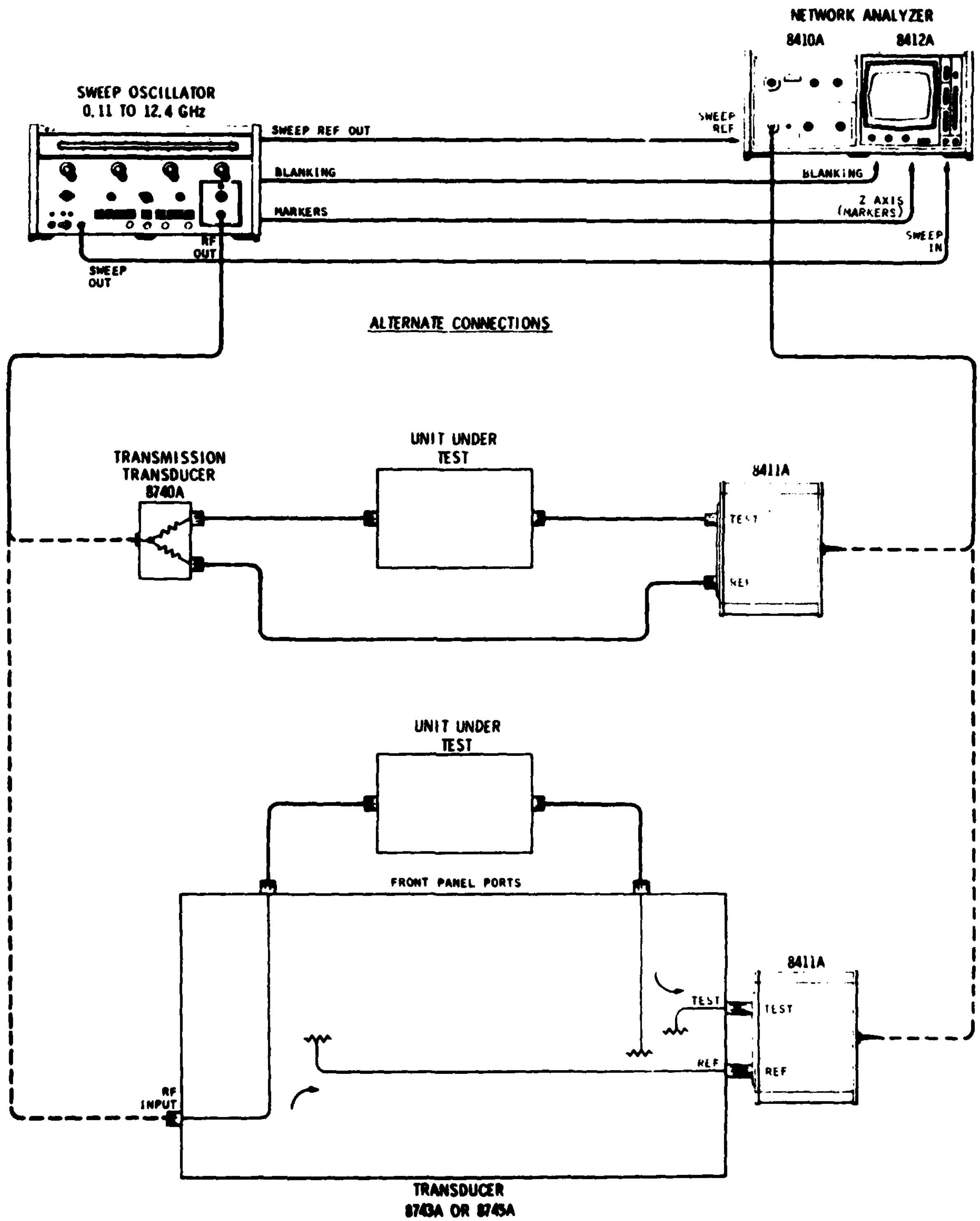
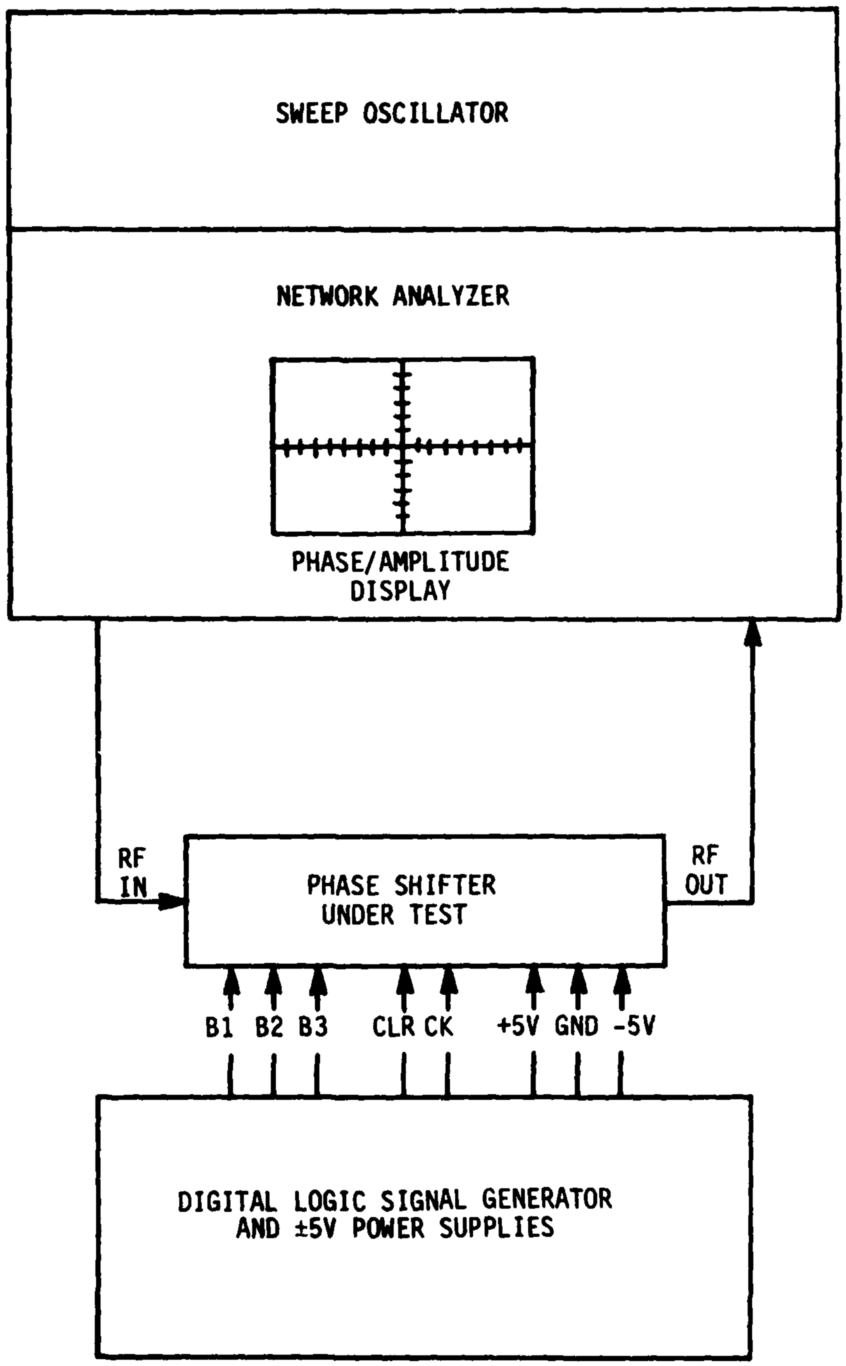


FIGURE 7 TYPICAL TRANSMISSION TEST SETUP

FIGURE 8 PHASE SHIFTER TEST SETUP BLOCK DIAGRAM



ELECTRICAL SPECIFICATIONS:

Frequency: 7.25 to 7.75 GHz

L.S.B.: 45^{0} Phase Shifter

Accuracy: $\pm 7.5^{0}$

Insertion Loss: $\leq$ 2.5dB Max.

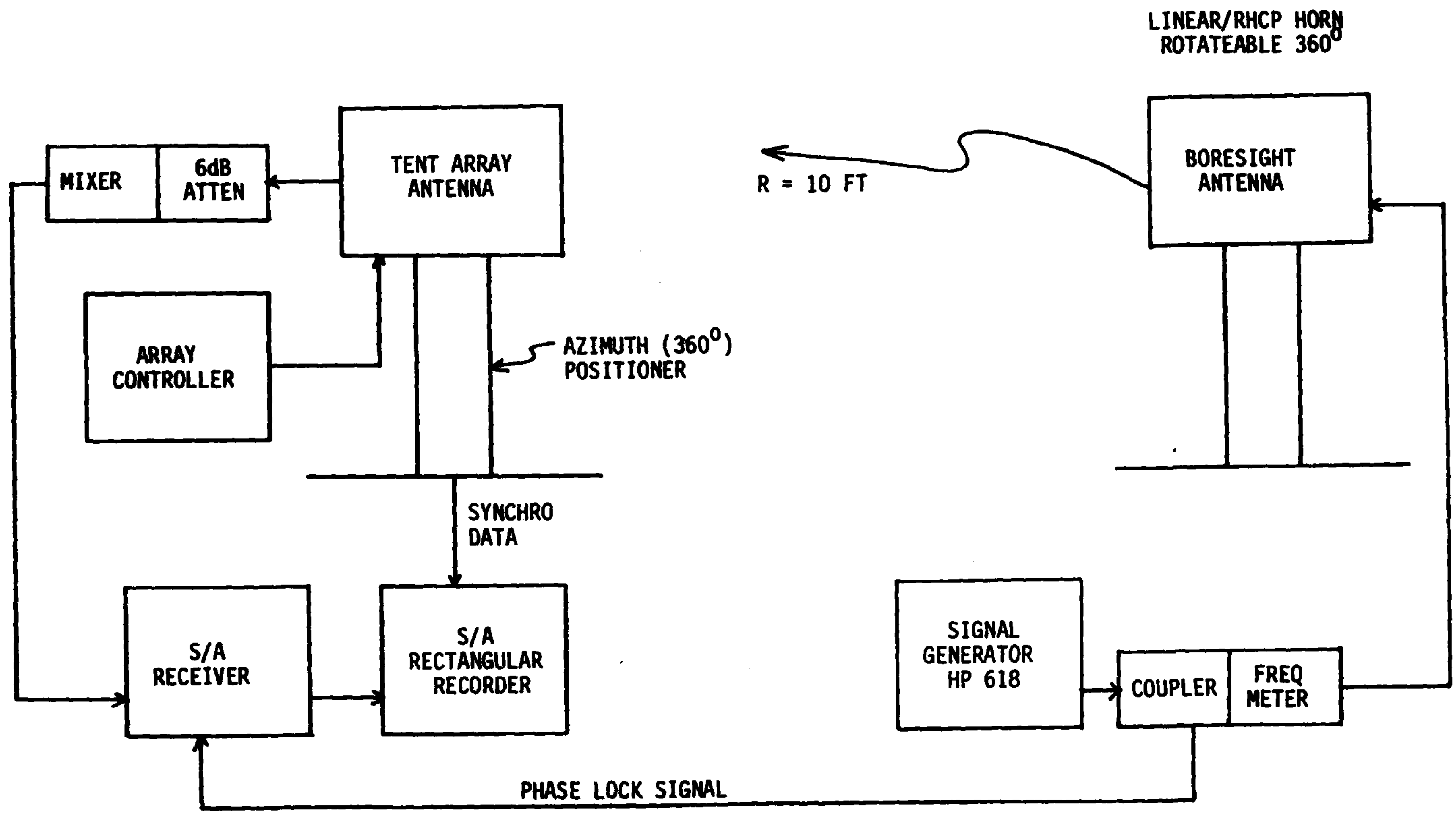
VSWR: 1.35:1 Max (> 16.5dB Return Loss)

RESET/CLOCK TRANSITION IS H → L → H

BIT 3	BIT 2	BIT 1	PHASE MEASUREMENT (DEGREES)	I+ 5V SUPPLY (ma)	I- -5V SUPPLY (ma)	INSERTION LOSS (dB)	RETURN LOSS (dB)	VSWR
0	0	0	0^{0} REF	45	320	2.4	20	1.22
0	0	1	44^{0}	150	210	2.4	22	1.17
0	1	0	91^{0}	145	220	2.3	24	1.13
0	1	1	136^{0}	250	100	2.4	19	1.25
1	0	0	180^{0}	160	200	2.5	18	1.30
1	0	1	225^{0}	260	100	2.4	18	1.30
1	1	0	269^{0}	270	90	2.4	20	1.22
1	1	1	315^{0}	375	10	2.4	22	1.17

TABLE 2 TEST DATA FOR A TYPICAL ACCEPTABLE PHASE SHIFT UNIT

FIGURE 9 TENT ARRAY PATTERN/AXIAL RATIO TEST SETUP



4.0 EXPERIMENTAL RESULTS

This section summarizes the experimental results obtained on the breadboard array. These results include active element patterns of array elements in the array environment, array scan performance patterns, axial ratio performance vs. scan angle, and array gain performance.

Experimental results presented here represent preliminary testing data of the breadboard. No attempts were made to match the active impedance performance of the array. Components were not tuned for optimum array operation.

4.1 Active Element Patterns. The radiation patterns in elevation and azimuth of an isolated array element and for each element in a passive array environment (active element patterns) were measured using a circularly polarized transmitting test antenna in a small anechoic chamber.

The location of each element in the array and the directions associated with the elevation and azimuth pattern principal planes are shown in Figure 10. The patterns for the isolated element number 10 at 7.25 GHz and 7.5 GHz are shown in Figure 11. Figure 12 shows the active element patterns of element number 10 measured at 7.25 GHz and 7.9 GHz. The active element patterns measured for each of the array elements at 7.5 GHz are shown in Figure B-1 through B-12 of Appendix B.

No unexpected anomalies are revealed in these patterns. Active element patterns exhibit beamwidths considerably narrower than the corresponding isolated element patterns, reflecting the effect of mutual coupling among the array elements. The elements of the breadboard array are spaced at a distance of 1.09" (.69λ at 7.5 GHz). Element spacing can be adjusted and optimized to broaden the active element pattern, and therefore reduce scan losses.

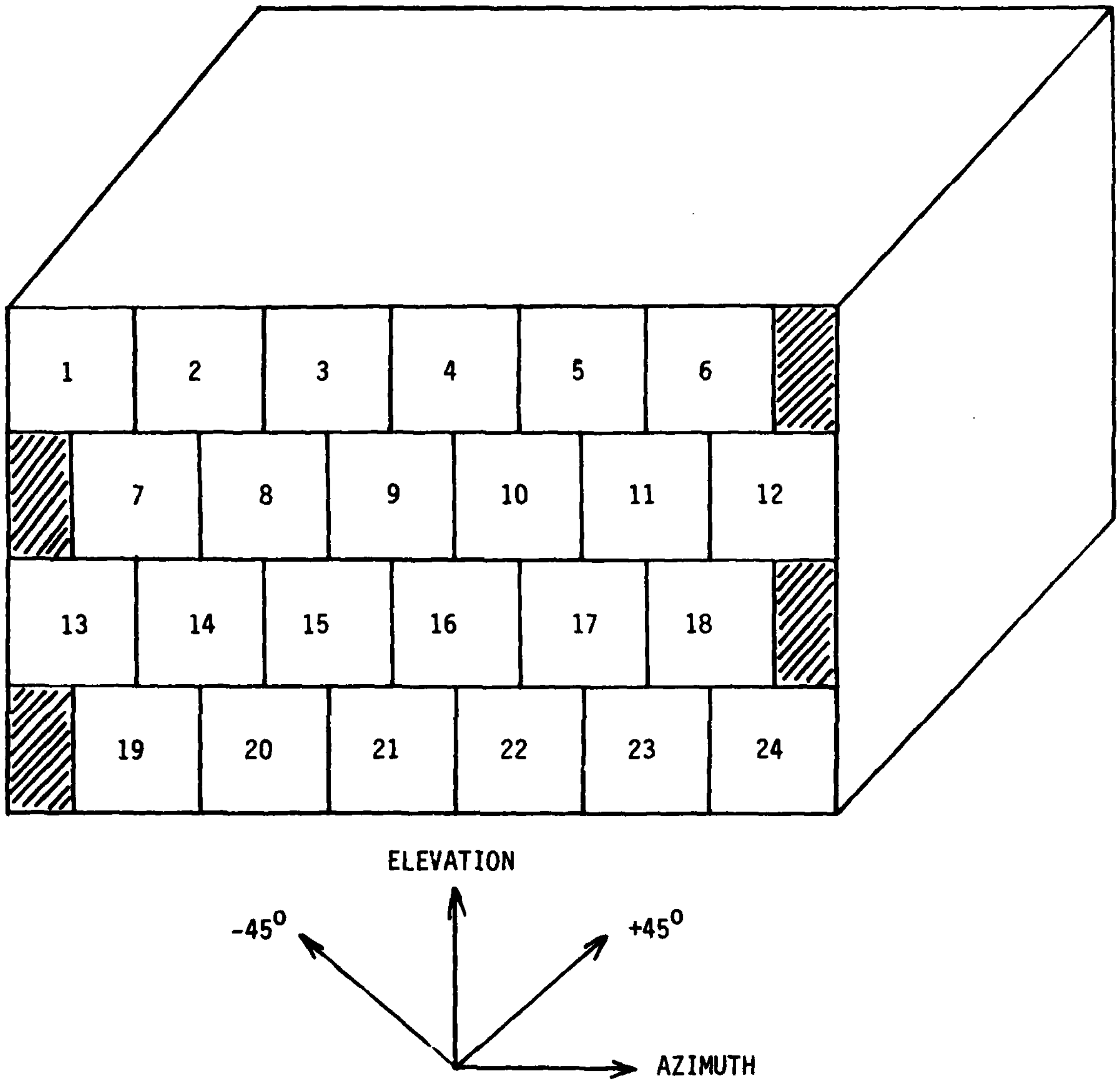
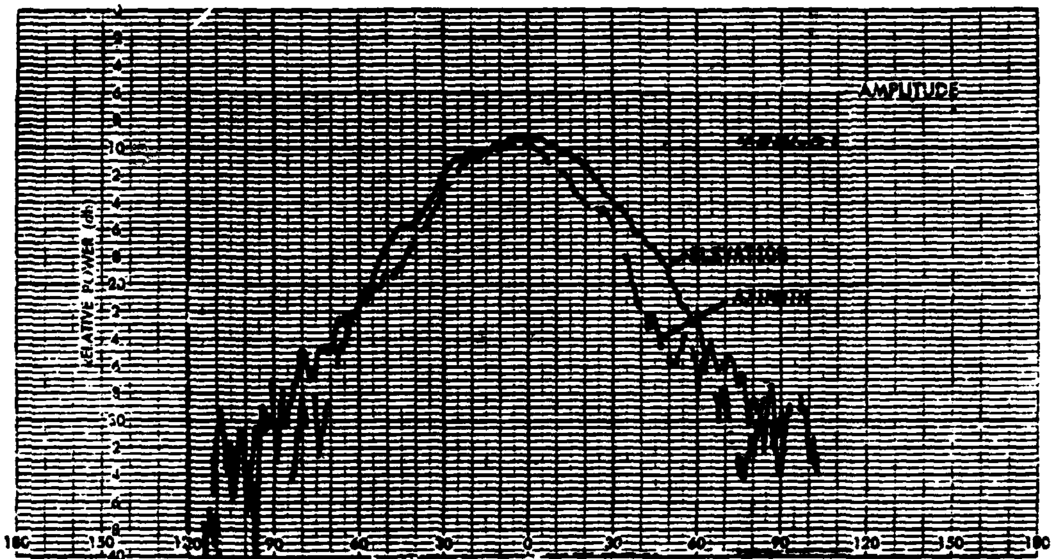


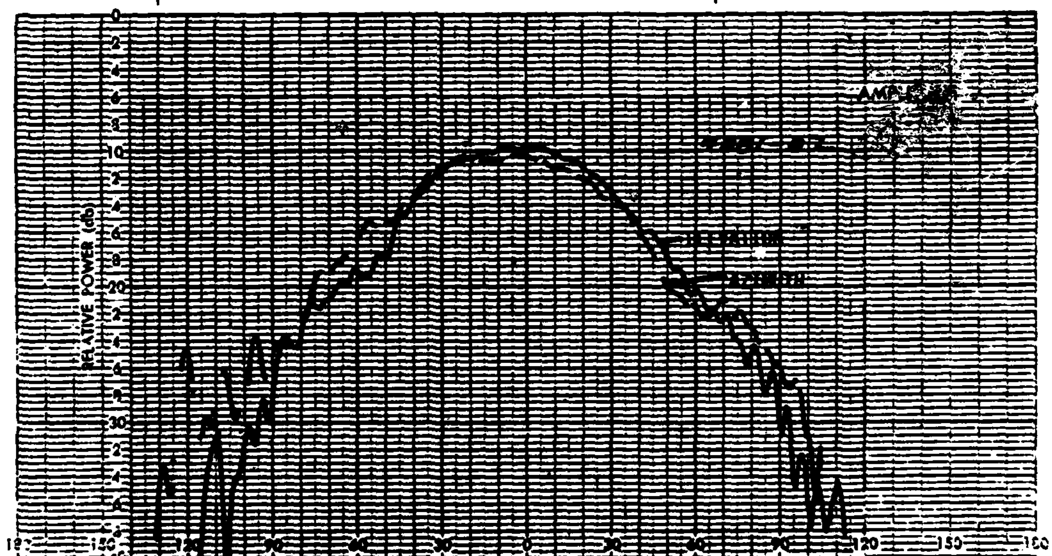
FIGURE 10 TENT ARRAY ELEMENT CELL INDEX NUMBERS AND PATTERN MEASUREMENT PLANE DIRECTIONS



PROJECT TENT ARRAY
MODEL BB ELEMENT #10
FREQUENCY 7.25GHz
PLANE Rx CP
DATE 04/08/81

ISOLATED ELEMENT PATTERNS

HARRIS



PROJECT TENT ARRAY
MODEL BB ELEMENT #10
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ISOLATED ELEMENT PATTERNS

HARRIS

FIGURE 11

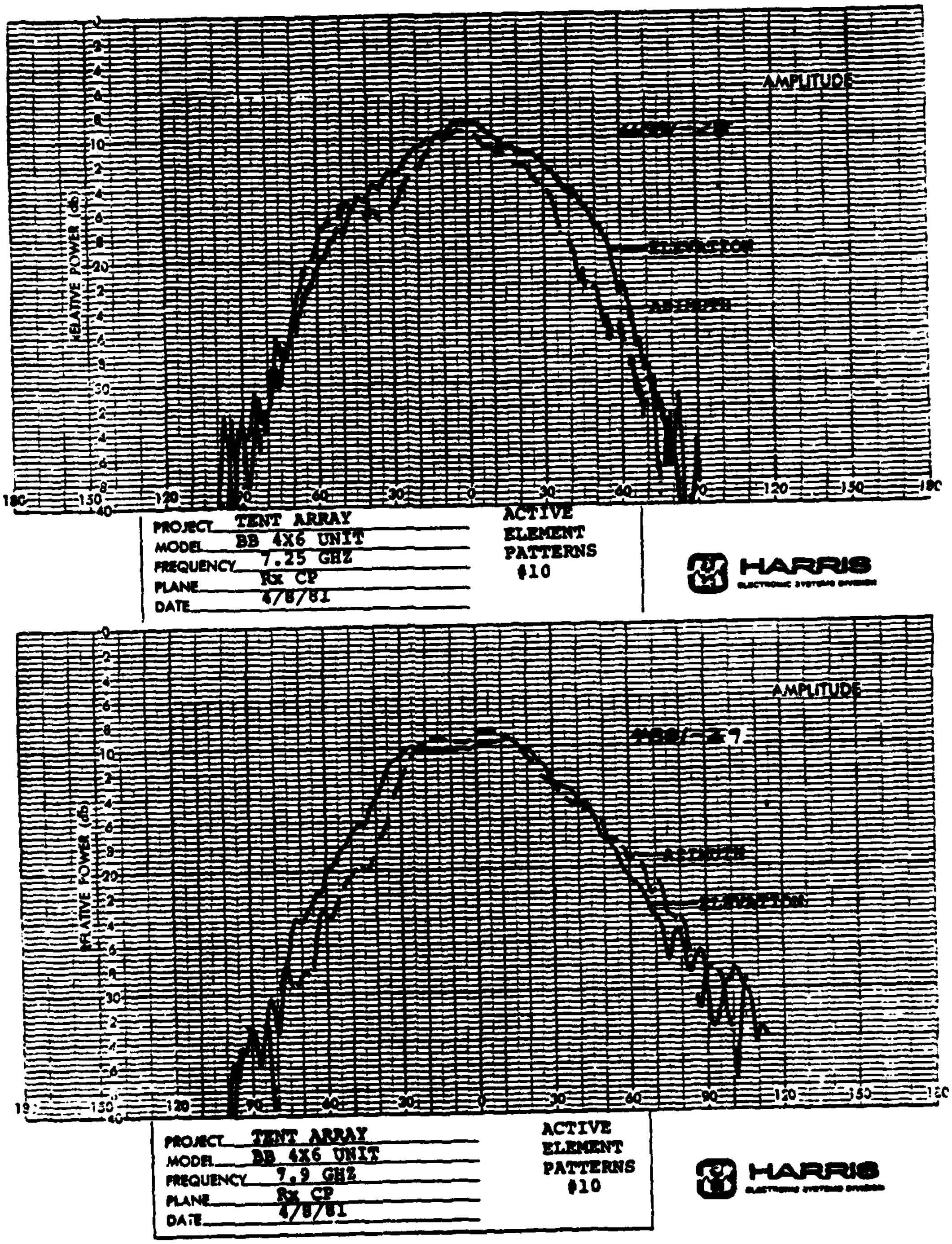

AMPLITUDE
ELEVATION
AZIMUTH
RELATIVE POWER (db)
PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE Rx CP
DATE 4/8/81
ACTIVE
ELEMENT
PATTERNS
#10
HARRIS
AMPLITUDE
AZIMUTH
ELEVATION
RELATIVE POWER (db)
PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.9 GHZ
PLANE Rx CP
DATE 4/8/81
ACTIVE
ELEMENT
PATTERNS
#10
HARRIS

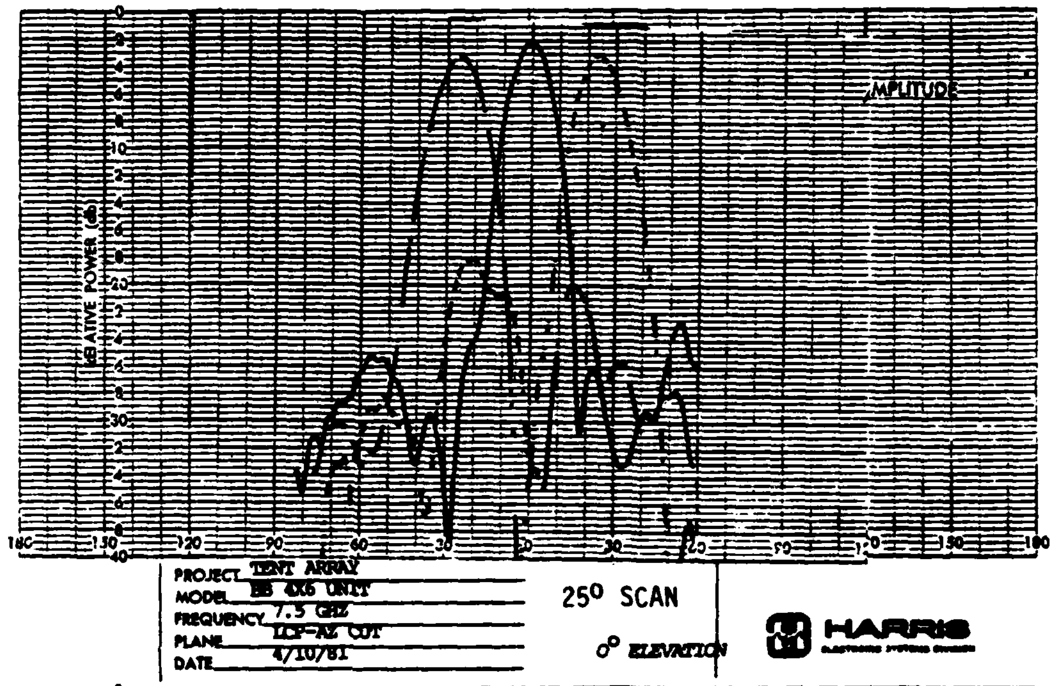
FIGURE 12

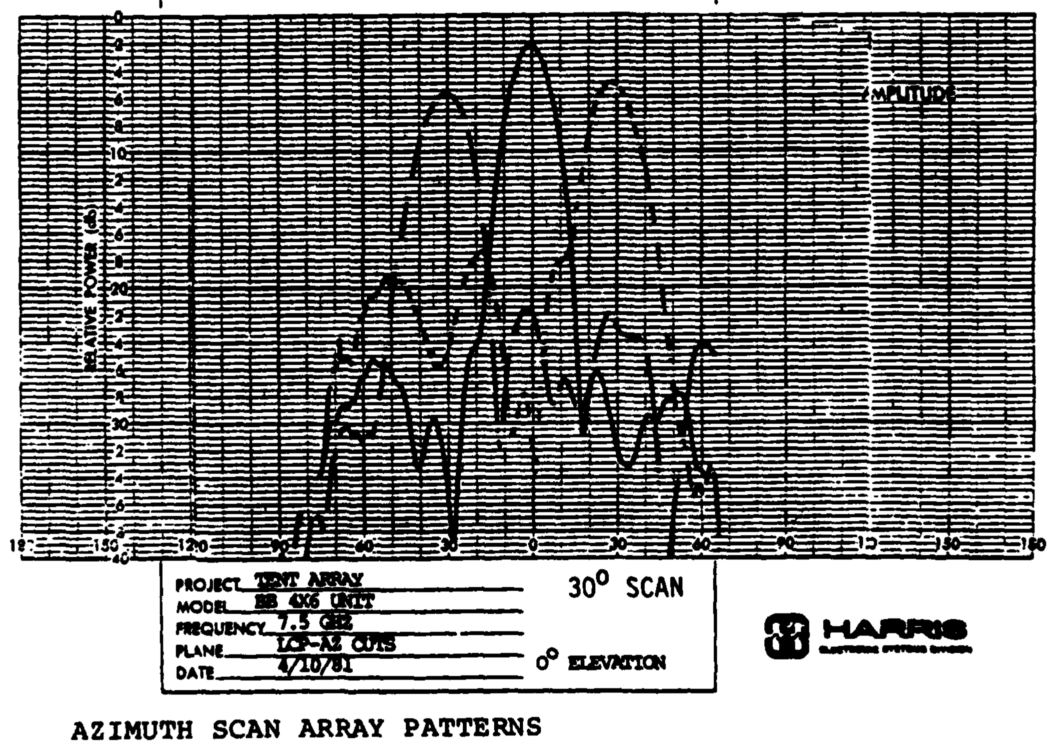
Patterns of elements clustered near the center of the array, i.e., numbers 9, 10, 15 and 16, exhibit the symmetry one would expect of these elements due to the symmetry of their mutual coupling environment. Pattern asymmetries are apparent in the active patterns of edge elements, i.e., element number 2, in both elevation and azimuth due to their asymmetrical environment. Since the array cannot be classified as a "large" array, these asymmetries will influence the overall array scan loss performance to the extent that scan loss performance cannot be accurately inferred from any one active element pattern "fall-off" at an angle of 30 degrees. Rather, scan loss will be the integrated effect of all active element patterns at 30 degrees.

4.2 Array Scan Performance. Radiation patterns are recorded in the principal planes (elevation and azimuth) and in -45 degrees and +45 degrees of scan plane (as defined in Figure 10) of the array. For 45 degrees scan planes, the scanned beam positions of these patterns were obtained by implementing equal azimuth (AZ) and elevation (EL) beam motions in 5 degree increments as noted on the patterns. As a consequence, the beam scan angle in the 45 degree scan planes exceeds 30 degrees when AZ = EL = 30°.

Typical patterns scanned at 25° and 30° of the azimuth plane are shown in Figure 13. Other measured scanning patterns are given in Figures B-13 through B-34 of Appendix B. These patterns exhibit significant scan losses for beams scanned more than 20° off boresight, due to excessive mutual coupling effects. Maximum sidelobes of the antenna patterns are higher than expected values of: -20dB in azimuth and -12dB in elevation planes.

Major sources of higher sidelobes and scan loss include active element effects, 3 bit phase shifter quantization and implementation errors, finite array effects, and test range effects. A small finite breadboard affects the array performance in two ways. First, the edge effects of a small array and its corresponding active element pattern contribute more to the array pattern than the large ones. Secondly, the required amplitude taper for sidelobe control is more subject to implementation





AZIMUTH SCAN ARRAY PATTERNS

FIG. 13

error in a small array. One of the significant contributors to higher sidelobes of the measured patterns is the reflection and scattering from the mechanical devices used to hold the breadboard and from other structures of the measurement set-up. The sidelobe level of the breadboard can be reduced in a better testing environment. The use of a 4-bit phase shifter, optimum array spacing, active impedance matching, proper feeding phasing, and an accurate range set-up will certainly improve the performance of the array in a great degree. Nevertheless, a specified sidelobe requirement can be met through proper amplitude tapering.

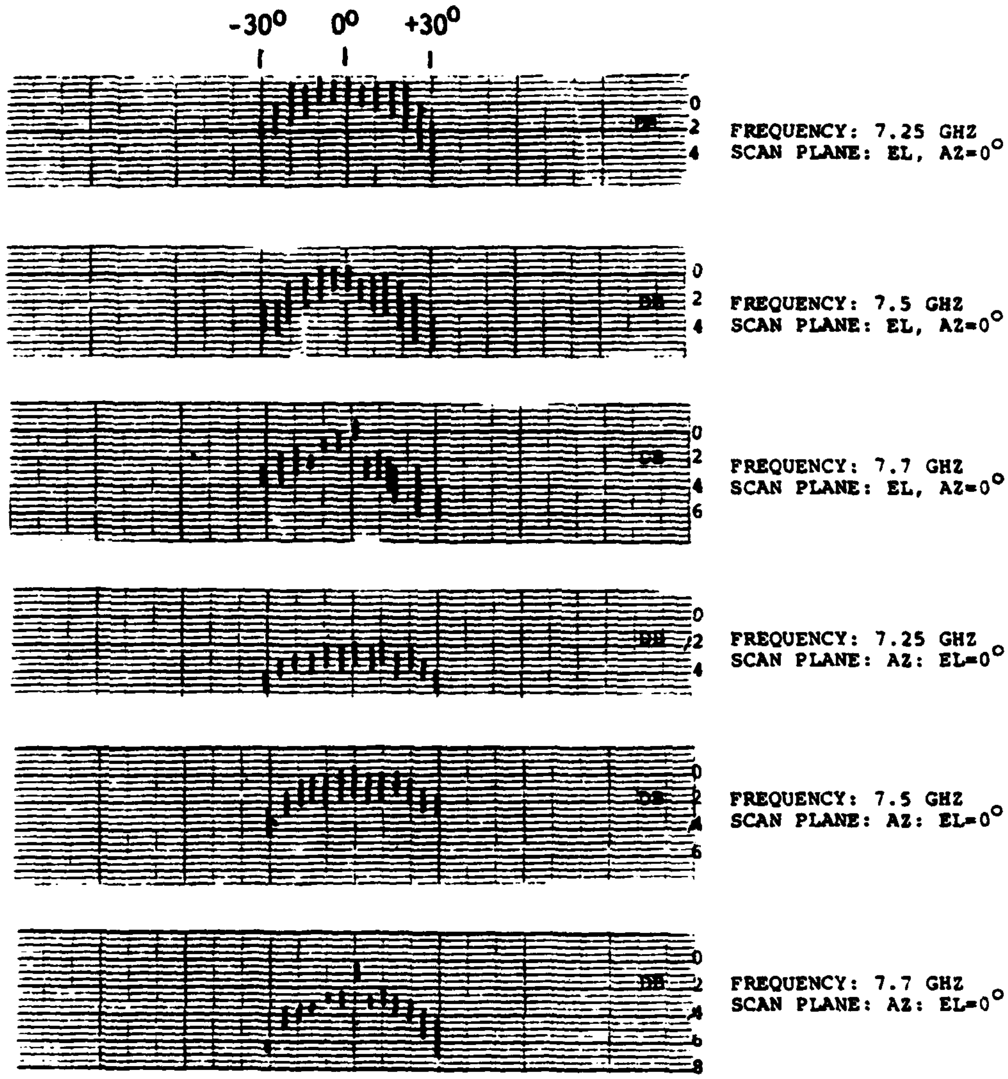
4.3 Axial Ratio Performance. Axial ratio performance of the integrated breadboard array assembly was obtained on the scanned beam maxima using a rotating linearly polarized horn. These data are shown in Figure 14 for the azimuth and elevation scan planes, and in Figure 15 for the ±45 degree scan planes.

The measured axial ratio of Figure 14 exceeds 3dB in only a few instances in elevation when the beam is scanned to the region lying between 20 and 30 degrees. At these isolated points, the axial ratio is 3.5dB.

The data for the ±45 degree scan planes deteriorate more rapidly as the beam is scanned toward 30 degrees. However, within the 30 degree scan limit the axial ratio exceeds 3dB in only a few instances in the +45 degree scan plane.

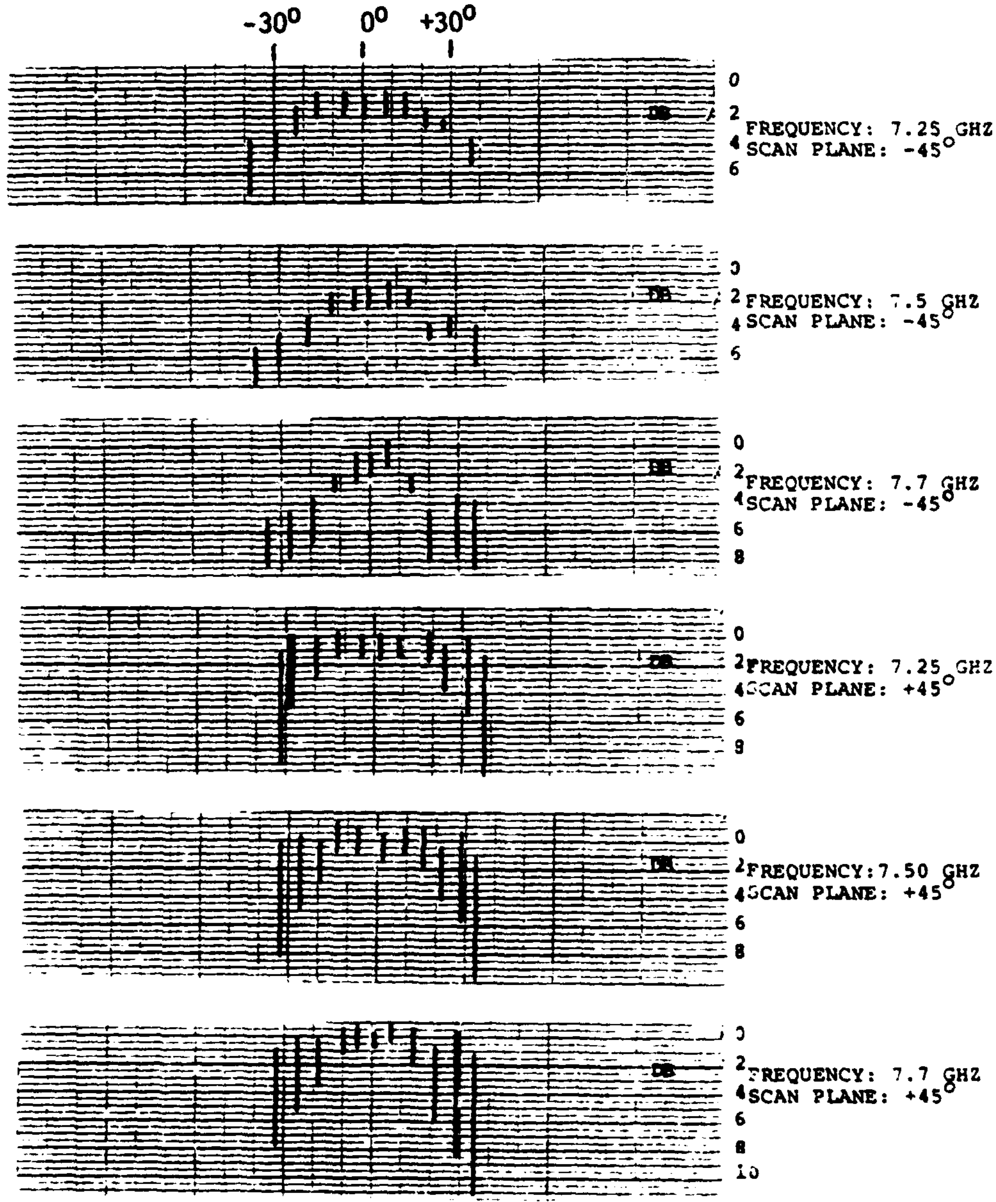
The axial ratio performance of the array can be improved by tuning the polarizers in the array environment. The array lattice and element spacing also play important roles in the array axial ratio performance.

4.4 Array Gain Performance. The gain performance of the breadboard array was determined by measuring the gain at broadside (zero scan angle) using a precalibrated linear gain standard. This gain figure was then corrected for axial ratio and scan loss.



TENT ARRAY AXIAL RATIO PERFORMANCE

FIG. 14



TENT ARRAY AXIAL RATIO PERFORMANCE

FIG. 15

POLARIZATION CORRECTION FACTOR FOR GAIN OF AN ELLIPTICALLY POLARIZED ANTENNA MEASURED WITH A LINEARLY POLARIZED GAIN STANDARD.

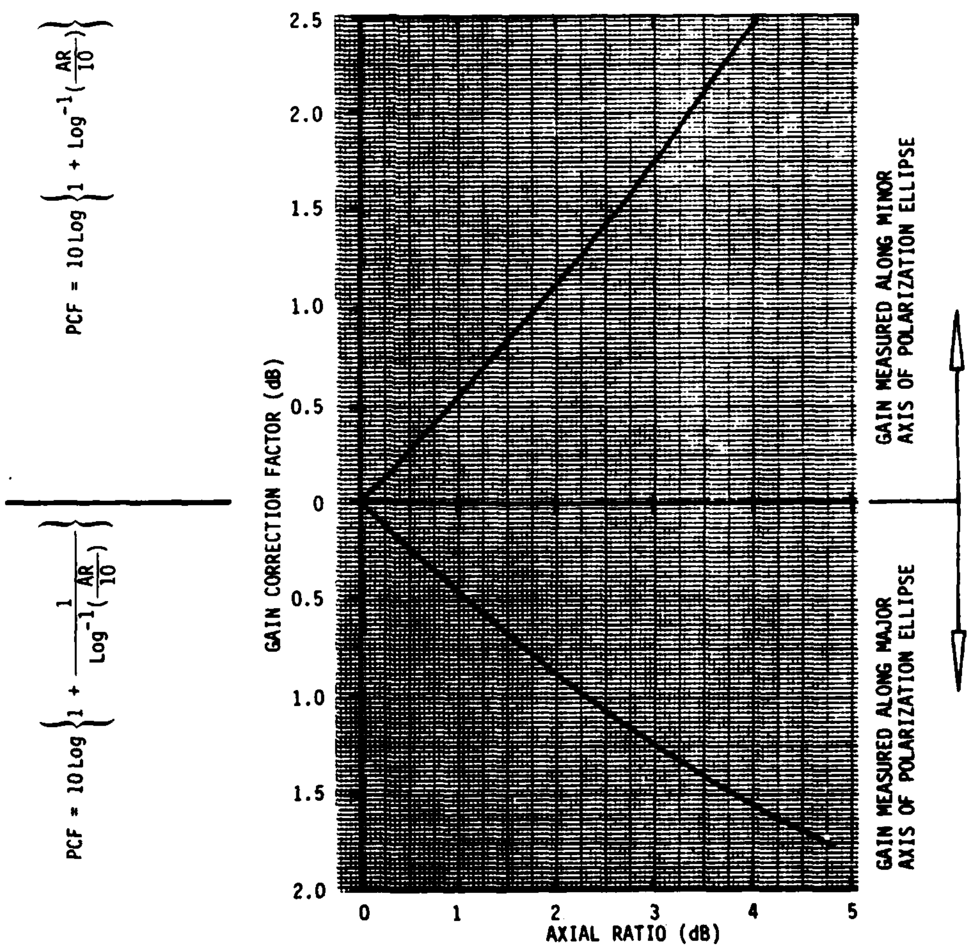


FIGURE 16

The average scan loss correction factor was derived from the patterns of Figures B-13 through B-34 of Appendix B using mainbeam levels at 30 degrees scan. It should be noted that the scan loss can be significantly improved through active impedance matching of the array aperture.

A summary of these data and the resulting gain calculation is shown in Table 3.

TABLE 3

BREADBOARD ARRAY GAIN ANALYSIS AT 7.5 GHz

Gain of Standard Horn	17.0dB
Differential Gain Measured	+ 1.0dB
Subtotal	18.0dB
Correction for boresight Axial Ratio of 1.7dB	.9dB
Subtotal	18.9dB
Correction for 30 Degree Scan Loss	- 3.3dB
Resulting Polarization Matched Array Gain (avg) at 30^{o} Scan	15.6dB

5.0 BREADBOARD TESTING AND TENT ARRAY DESIGN

Preliminary testing results of the breadboard array were not entirely compatible with the design specifications of the full tent shaped array. However, the integration and testing of the tent array breadboard indeed demonstrated the feasibility of tent array concepts. The performance of the final tent array design can be predicted. A discussion of the design considerations of the final tent array and the designs of a 20dB and a 30dB tent array are given in the following.

5.1 Design Considerations. The design considerations of the tent array discussed in the following include active impedance matching, feeding phase compensation, array depth, axial ratio, and digital control line coupling.

Active Impedance Matching. Preliminary testing on the scan performance of the breadboard exhibited significant scan losses, indicating mutual coupling effects. The use of simple matching pins and/or a thin dielectric sheet in the array aperture are examples of two feasible methods that could be used for active impedance matching and an improvement in scan loss.

Feeding Phase Compensation. Correct phasing of the array element feeding at the operating bandwidth plays an important role in the gain and sidelobe performance of a scanning array. The use of a nonconventional (nonbinary) feed network such as recommended for the tent array requires phase compensation for the entire frequency bandwidth. One of the potential phase compensation methods for the tent array is to use the microprocessor for phase error computation and for commanding the phase shifters to compensate the errors. The accuracy of the approach is limited by the available bits of the phase shifter.

Array Depth. Array depth has a significant impact on aerodynamic effects and array packaging. The components of the breadboard were fabricated for the purpose of breadboard testing. The depths of the waveguide elements including septum polarizers and the phase

shifters can be greatly reduced with additional electrical tuning and special mechanical integration techniques. However, the reduction of the depth in the septum type power dividers used for the breadboard is limited by the physical structures. Thus, we recommended the use of nonconventional feed network, shown in Figure 13 of the Interim Report, for the full scale tent array design. This entails the use of more sophisticated phase compensating and impedance matching techniques at the feeding structure. Nevertheless, the design goal of six inches in array depth is achievable with further development of compact array components.

Axial Ratio. The axial ratios of the breadboard array scanning patterns can be improved by first tuning the septum polarizers individually, and then in an array environment. The boresight axial ratios of the isolated septum polarizers were measured at .5 to .7dB. The values can be improved to .25dB with additional fine tuning.

Digital Control Line Coupling. During the breadboard testing, a severe coupling between the digital control lines was observed. It caused incorrect commanding of the phase shifters, and prevented the array from scanning. The digital control lines of the breadboard were cut properly for a temporary fix. For the tent array final designs, the use of differential pair driver IC's and shielded twisted pair cables is recommended.

5.2 20dB and 30dB Tent Arrays. The breadboard testing studied the performance characteristics of the components, and verified the feasibility of the tent array concept. The design parameters and configurations of a 20dB gain and a 30dB gain array are presented in Tables 4 and 5, respectively. The major difference is the array spacing for the end arrays due to the relative importance of element depth effects on the aerodynamic impact.

TABLE 4 THE DESIGN OF A TYPICAL 20DB GAIN TENT ARRAY

	Side Array	End Array	Total Array
Scan Sector	$\pm 63^{o}$	$\pm 30^{o}$	-
Tilt Angle	45^{o}	20^{o}	-
Minimum Coverage Gain (dB)	20	20	20
Total Losses (dB)	6.98	3.98	-
Directivity (dB)	26.98	23.98	-
Required Aperture Size (in^2)	105	52.6	-
Element Spacing (in)	.78	.78	.78
Array Depth - d* (in)	6	6	-
Array Height - h'* (in)	4.68	6.24	-
Array Width - W* (in)	22.62	8.56	-
Array Elements	6 x 29	8 x 11	-
Number of Elements	174	88	524
Overall Array Size:			
Height - H* (in)	8	8	8
Length - (in)	-	-	38
Radome Configuration			IE**

*The symbols of the array dimensions are illustrated in Figure 7 of the Interim Report.

**See Figure 10 of the Interim Report.

TABLE 5 THE DESIGN OF A TYPICAL 30dB GAIN TENT ARRAY

	Side Array	End Array	Total Array
Scan Sector	$\pm 63^{o}$	$\pm 30^{o}$	-
Tilt Angle	45^{o}	20^{o}	-
Minimum Coverage Gain (dB)	30	30	30
Total Losses (dB)	7.18	4.18	-
Directivity (dB)	37.18	34.18	-
Required Aperture Size (in^2)	1099	551	-
Element Spacing (in)	.78	.933	-
Array Depth - d (in)	6	7	-
Array Height - h' (in)	10.92	10.26	-
Array Width - w (in)	100.62	54.1	-
Array Elements	14 x 129	11 x 58	-
Number of Elements	1806	638	4888
Overall Array Size:			
Height - h (in)	12	12	12
Length - (in)	-	-	119
Radome Configuration			Modified 1E*

*See Figure 10 of the Interim Report.

6.0 CONCLUSION AND RECOMMENDATIONS

The tent shaped phased array, capable of electronic scanning for hemispheric coverage, is a promising candidate for a lightweight, low drag SHF aircraft antenna for satellite communications. Utilizing square waveguide elements, septum polarizers, and a unique feed network, it offers the capability of high power transmit and dual polarization operations. The use of a microprocessor provides the flexibility and the desired versatility for beam control and feeding phase error correction. The development and design of compact array components and array packaging is the key factor to the success of tent array applications.

A 4 x 6 element breadboard array was designed, fabricated, and tested. Active element patterns and scanning patterns were measured. A strong crosstalk among the digital phase shifter controller lines experienced during the breadboard testing, suggested the use of differential pair driver IC's and shielded twisted pair cables. Significant scan loss was caused by the effects of mutual coupling at the array aperture. Nevertheless, preliminary testing demonstrated the feasibility of the tent array concept. The performance of the full scale tent array is predictable. Further studies are recommended in the following areas:

- Breadboard testing - additional breadboard tests and gain calibration are needed in an accurate range set-up with minimum range reflections. Additional tests include the measurements of scanning patterns, active impedances, and coupling coefficients.
- Active Impedance Matching - effective active impedance matching methods include the use of a dielectric sheet and/or simple matching pins in the array aperture.
- Compact Feed Network - the coupling effects and impedance matching of the nonconventional feed network require further study.
- Ground Plane Effects - the breadboard can be mounted on a simulated host vehicle ground plane for pattern measurements and performance characterization.

APPENDIX A

TENT SHAPED PHASED ARRAY

PROGRESSIVE PROJECT DOCUMENT (PPD)

SOFTWARE DESIGN APPROACH

FUNCTIONS TO BE PERFORMED :

I. INITIALIZE

A) PRINT HEADER

B) READ LOOK-UP TABLE - DATA BASE

II. INPUT AZIMUTH AND ELEVATION

A) PRINT RANGE AND INSTRUCTIONS

B) REJECT NONSENSE AND OUT OF RANGE DATA

III. SET PHASE SHIFTERS FOR PATTERN

A) RETRIEVE 24 PHASE SHIFTER VALUES

B) PROGRAM PHASE SHIFTERS THROUGH THE PARALLEL PORT

IV. EDITOR MODE

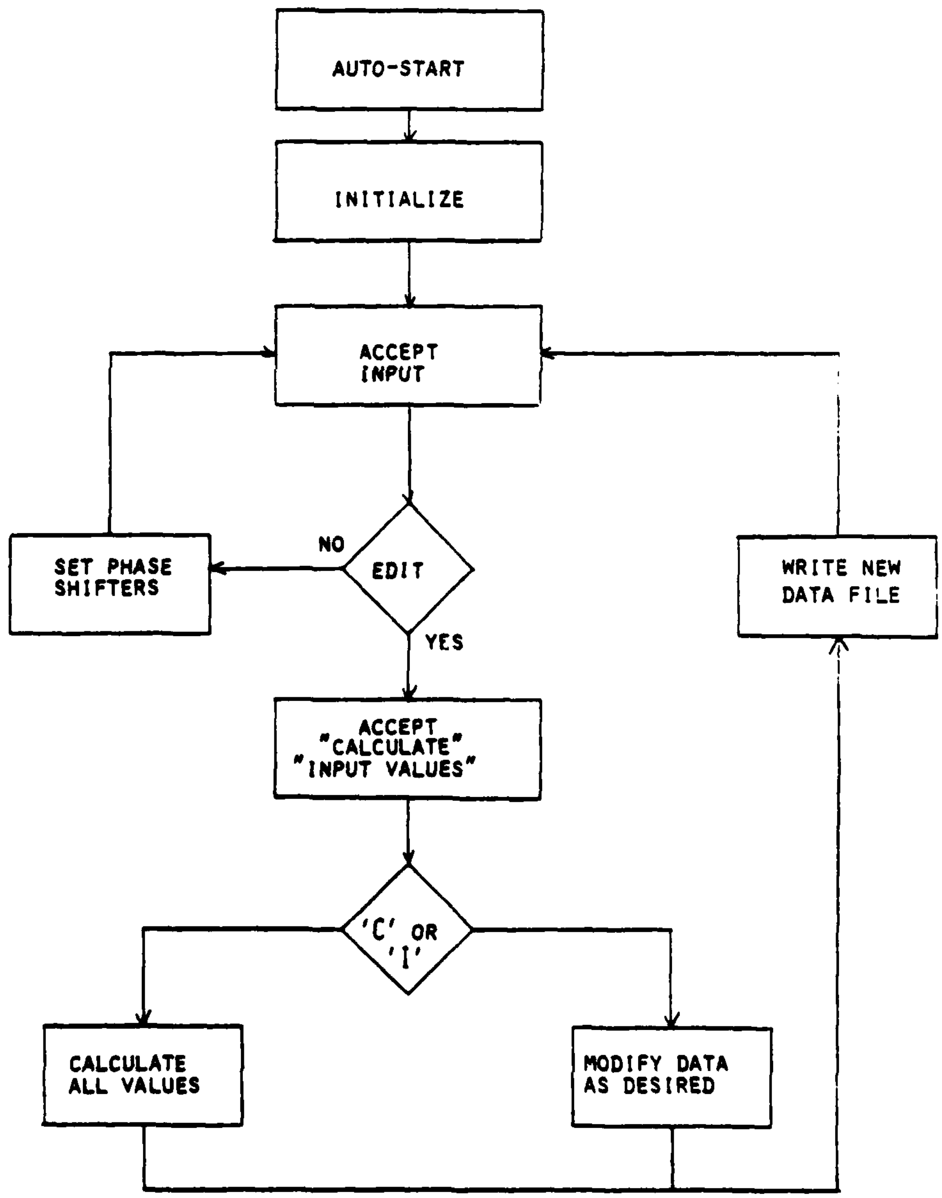
A) SELECT CALCULATIONS OR INDIVIDUAL VALUE INPUT

B) PERFORM CALCULATIONS IF SELECTED

C) ENTER AND DISPLAY VALUES FOR ANY AZIMUTH AND ELEVATION POSITION DESIRED IF SELECTED

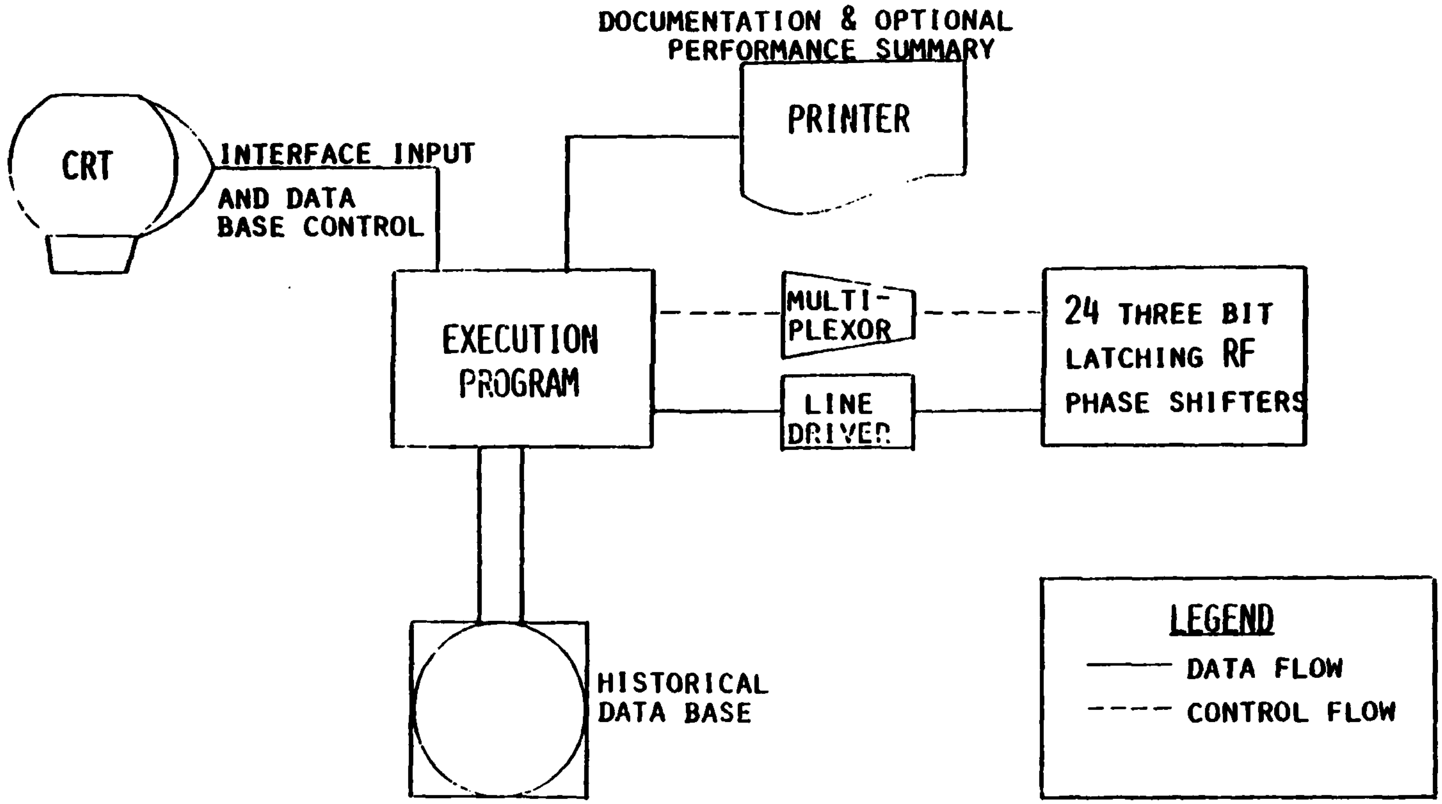
D) REWRITE DATA BASE LOOK-UP FILE AND RETURN TO OPERATING MODE

SOFTWARE DESIGN APPROACH

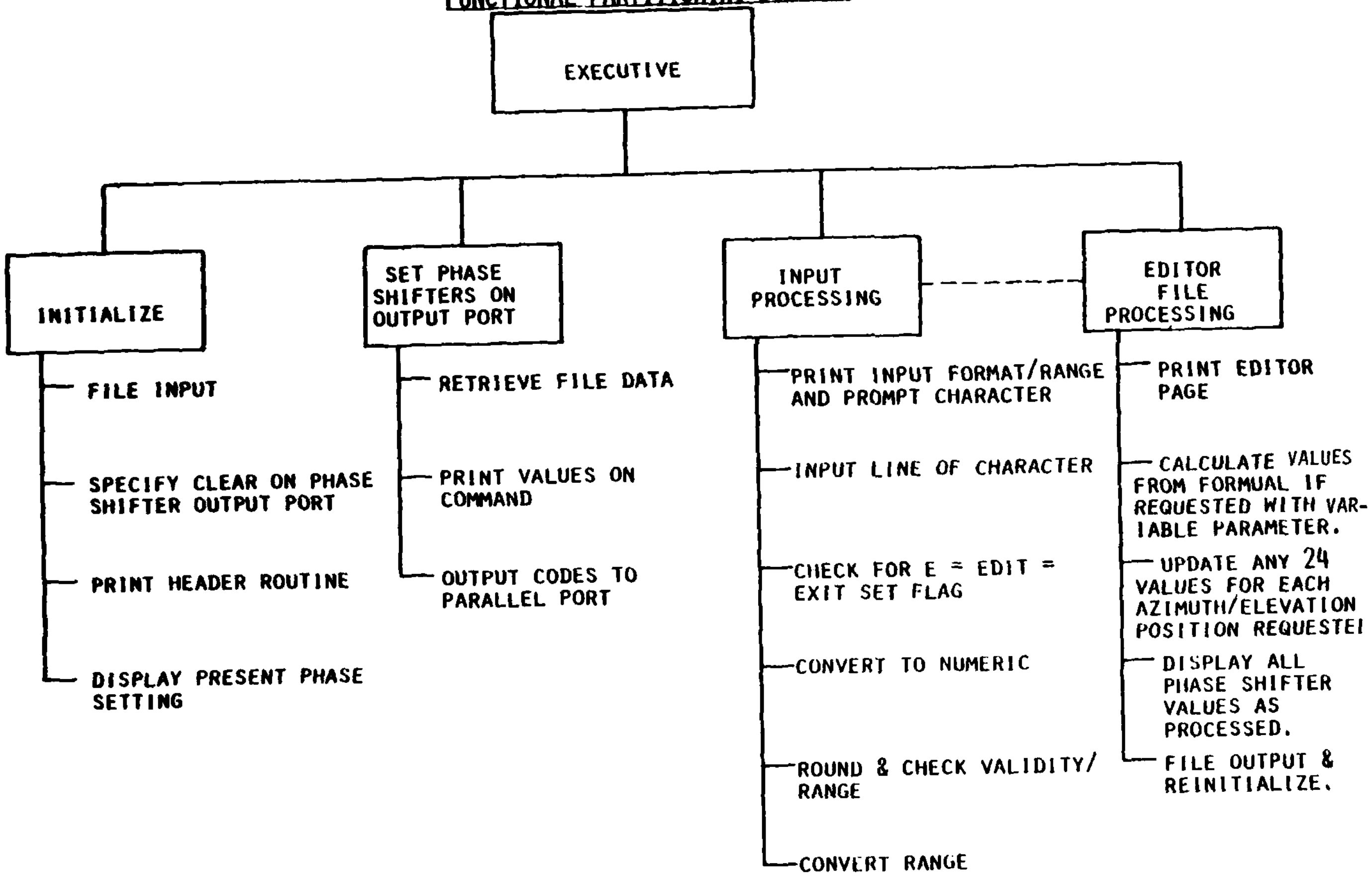


TENT ARRAY PPD

SYSTEM CONTROL AND DATA FLOW DIAGRAM



TENT ARRAY PPD
FUNCTIONAL PARTITIONING DIAGRAM



TENT ARRAY PPD

SYSTEM SUMMARY

IDENTIFICATION AND EXECUTIVE

SUMMARY

This document presents development information regarding the TENT SHAPED PHASED ARRAY as generated through the Phase I breadboard development.

The purpose of this system is to study the electrical and mechanical concept of designing a low drag aircraft antenna capable of electronically scanning the upper-hemisphere on both receive and high-power transmit. A controller is used to set the phase shifters through digital control. This produces RF phase changes across the face of the antenna and alters the antenna pattern in a controlled manner. The controller points the beam in the direction prescribed by manipulating the phase shifter values. It is also necessary during the testing phase to modify or optimize the values sent to the phase shifters for the various pattern positions. This function is implemented through an editor in the array controller program.

TENT ARRAY PPD

CONFIGURATION MANAGEMENT

Modification procedures shall be under the control of the Project Manager and the Controller Design Engineer or their appointed representative. The procedure and method for modification/revision shall be the ECO document.

TERMS AND ABBREVIATIONS

AZ	=	Azimuth Position
EL	=	Elevation Position
RADC	=	Rome Air Development Center
ROWH	=	High (tens) Digit of the ROW number
ROWL	=	Low (ones) Digit of the ROW number
COLH	=	High (tens) Digit of the Column Number
COLL	=	Low (ones) Digit of the Column Number
COL	=	Column

TENT ARRAY PPD

PROGRAM DEFINITION DOCUMENTS

I. Tent Shaped Phased Array Proposal

   A) Technical Proposal Vol. #1
      RFP F19628-79-R-0092

   B) Cost Proposal Vol. #2
      RFP F19628-79-R-0092

   C) Executive Summary
      RFP F19628-79-R-0092

II. Tent Array Program #1585
    Subtask Controller R-705

III. Pascal/Z Manual Version 3.0 LBISM-1-01
     Lifeboat Associates with Pascal/Z Version 3.2 Notes

IV. Pascal User Manual and Report Second Edition K. Jensen, N. Wirth

V. CP/M2 FDOS and Utilities Manual Lifeboat Associates

VI. CP/M2 on Northstar Version 2.2 User Notes
    Lifeboat Associates

TENT ARRAY PPD

OPERATIONAL SCENARIO

The equipment is powered up by the main power switches on the rear right side of 1) The HP 2621A CRT, 2) the ANACOM 150 Line Printer and 3) The Northstar Horizon in the stated order. The system operating disc is in the left disc drive A. The program is automatically invoked and prints the header, reads the file, sets the array on boresight and provides input instructions. An azimuth value is entered in degrees followed by an elevation value. Any incorrect input (nonsense or out of range data) is ignored and a new value accepted until good data is entered. The electronic scan is executed by programming the phase shifter values and the display is updated following the elevation value entry and a new position is requested.

To use the editor an 'E' is entered for the azimuth or elevation value and the screen is cleared for the editor header. The question

TENT ARRAY PPD

ENTER 'C' FOR AUTOMATIC CALCULATIONS OR 'E' FOR ENTERING PHASE SHIFTER VALUES.

Prompts the operator to select the editor mode. If 'C' is entered for calculations the operator enters the variable d in wavelengths (0.5 nominal) for the sin·sin + sin·cos phase shifter calculations. The data array is then filled with the calculated values and the edit mode exited. If 'E' is entered the operator then enters the azimuth and elevation values, as in the normal operating mode, and can then update the positions 24 phase shifter values. When 'E'xit is entered for the azimuth or elevation value the new data file is written to the disc and the header page displayed for boresight position. Operation may then continue in the normal operating mode.

IMPACTS

Data maintenance will cease following the testing phase and the editor mode will be removed from the program. The customer will only operate the system in the normal operating mode.

ASSUMPTIONS AND CONSTRAINTS

The array could be expanded to 32 phase shifters with minimal hardware and software modifications. Larger expansions would require major re-design of both hardware and software.

TENT ARRAY PPD

REQUIREMENTS DOCUMENTATION

PURPOSE

This documentation establishes the baseline requirements on which to base the design process. Updates are made throughout the development process to ensure consistency.

OVERVIEW

The functional partitioning diagram included in this package shows the relationship of all major functions. A Control and Data flow diagram, also included, details the delineated major functions of internal and external interfaces.

MAJOR FUNCTION "INITIALIZE"

The purpose of this function is to clear all phase shifters with a reset pulse, print the header on the CRT, and read the data base stored on the floppy disc. It initializes the loopup table used to set the antenna beam to some azimuth and elevation position. The initialization function leaves the beam pointed on boresight (azimuth = 0°, elevation = 0°) and displays this setting on the CRT screen.

TENT ARRAY PPD

REQUIREMENTS DOCUMENTATION

MAJOR FUNCTION "SET PHASE SHIFTERS"

The purpose of this function is to set the twenty-four three-bit phase shifters to a set of values defined in the lookup table at a particular azimuth and elevation coordinate set. The values are stored as a code containing the multiplexor control and data so that it is only necessary to access the data base for each phase shifter in the azimuth and elevation set, and dump it to the parallel port interface.

MAJOR FUNCTION "DATAIN"

The purpose of this function is to interactively acquire the azimuth and elevation values and convert them to indexing integers for accessing the lookup table data base. The output of the routine is two integer-bytes in the range of zero to fourteen corresponding to azimuth and elevation values in the range of -35 to +35 degrees rounded to 5 degree intervals. This function utilizes a sub-function CONVERT to deal with nonsense and out of range data for program robustness which is described later.

MAJOR FUNCTION "EDITOR"

The purpose of this function is to allow modification of the lookup table data base during the testing phase of

the program. It accepts as input a character 'C' or 'I' to either calculate all phase shifter values from a formula or to individually enter each of 24 phase shifter values at any azimuth/elevation position. The editor utilizes the major function "DATAIN" in the 'E'nter portion and another function "CALCULATE" for the calculation portion. A new display is printed on the screen and data is displayed as it is calculated or input manually.

FUNCTION DATAIN.CONVERT

The input major function DATAIN utilizes function CONVERT to input a line of alphanumeric characters and decode commands and data while eliminating nonsense input. The routine is described by the PDL code and recognizes the commands to set appropriate flags, while converting data into integer format.

FUNCTION EDITOR.CALCULATE

The major function EDITOR utilizes function CALCULATE to perform the phase value calculations on all the phase shifters at every azimuth and elevation position. Inputs are the delta-D value while outputs are the three-bit phase shifter values and multiplexor codes entered into the data array. A PDL description of this routine describes the

coordinate transformation and sin·cos + sin·sin calculations resulting in the phase value and the conversion to the three bit value.

PERFORMANCE

The controller shall set the array to the desired position within 500mS. The data base contains 5400 bytes of data to point the beam every five degrees between -35 and +35 degrees of both azimuth and elevation.

FAILURE AND ERROR CONTINGENCIES

The backup procedure for the program is three separate duplicate copies of the program disc containing monitor, program, and data base. The fallback or restart procedure is automatically enabled through the autostart of the running program on both cold (power-up and reset) and warm boot (control-c) operations. Error contingencies are handled on the input CONVERT routine for data entry. There are no contingencies for major hardware failure.

INTERFACE REQUIREMENTS OVERVIEW

Three interfaces exist within the system. The first

is the CRT interface on an RS-232 bus transmitting standard ASC II. The second is the Printer interface also on an RS-232 bus transmitting ASC II. Both these interfaces operate at a 9600 BAUD rate.

TENT ARRAY CONTROLLER

OPERATION SEQUENCES

The tent array controller is installed with three simple cable connections. After the master floppy disc is inserted and power switch energized the running program is automatically started. The terminal then displays an entry page with the "HARRIS TENT ARRAY" header and brief instructions for how to operate the command explanation page or set the array coordinates. An array of phase shifter values is stored on the floppy disc. These values are used by the program to steer the beam when the azimuth and elevation values are entered. A program module can be invoked which allows table modification and update for the test and modification phase of the program.

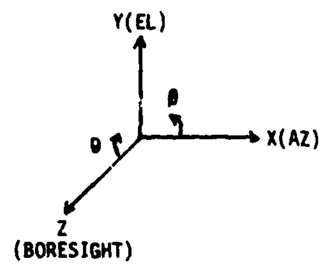
(ROW_i, COL_i)	#1 (-3,2)	#2 (-2,2)	#3 (-1,2)	#4 (0,2)	#5 (1,2)	#6 (2,2)	COL. #2
	#7 (-3.5,1)	#8 (-2.5,1)	#9 (-1.5,1)	#10 (-0.5,1)	#11 (0.5,1)	#12 (1.5,1)	COL. #1
	#13 (-3,0)	#14 (-2,0)	#15 (-1,0)	#16 (0,0)	#17 (1,0)	#18 (2,0)	COL. #0
	#19 (-3.5,-1)	#20 (-2.5,-1)	#21 (-1.5,-1)	#22 (-0.5,-1)	#23 (0.5,-1)	#24 (1.5,-1)	COL. #-1

ROW Ø

$\Delta AZ = 5^o$
$\Delta EL = 5^o$

$AZ = i \cdot \Delta AZ$
$EL = j \cdot \Delta EL$

$i, j = -7, -6, \ldots, +6, +7$



COORDINATE TRANSFORM

$$\theta = \sqrt{(AZ)^2 + (EL)^2}$$

$$\emptyset = TAN^{-1}\left(\frac{EL}{AZ}\right)$$

$\emptyset_K$ = PHASE SETTING OF K^{th} ELEMENT.

$$\emptyset_K = -\left\{(ROW_K)(2\pi)(360^o)\cdot(\Delta d)\cdot\left(SIN\sqrt{(AZ)^2 + (EL)^2}\right)\cdot\left(COS\left[TAN^{-1}\left(\frac{EL}{AZ}\right)\right]\right)\right\} + -\left\{(COL_K)(2\pi)(360^o)\cdot(\Delta d)\cdot\left(SIN\sqrt{(AZ)^2 + (EL)^2}\right)\cdot\left(SIN\left[TAN^{-1}\left(\frac{EL}{AZ}\right)\right]\right)\right\}$$

$$CODE = SHIFTER*8 + INT\left\{\frac{\emptyset_K \pm N*360}{45^o}\right\}$$

TENT ARRAY PPD

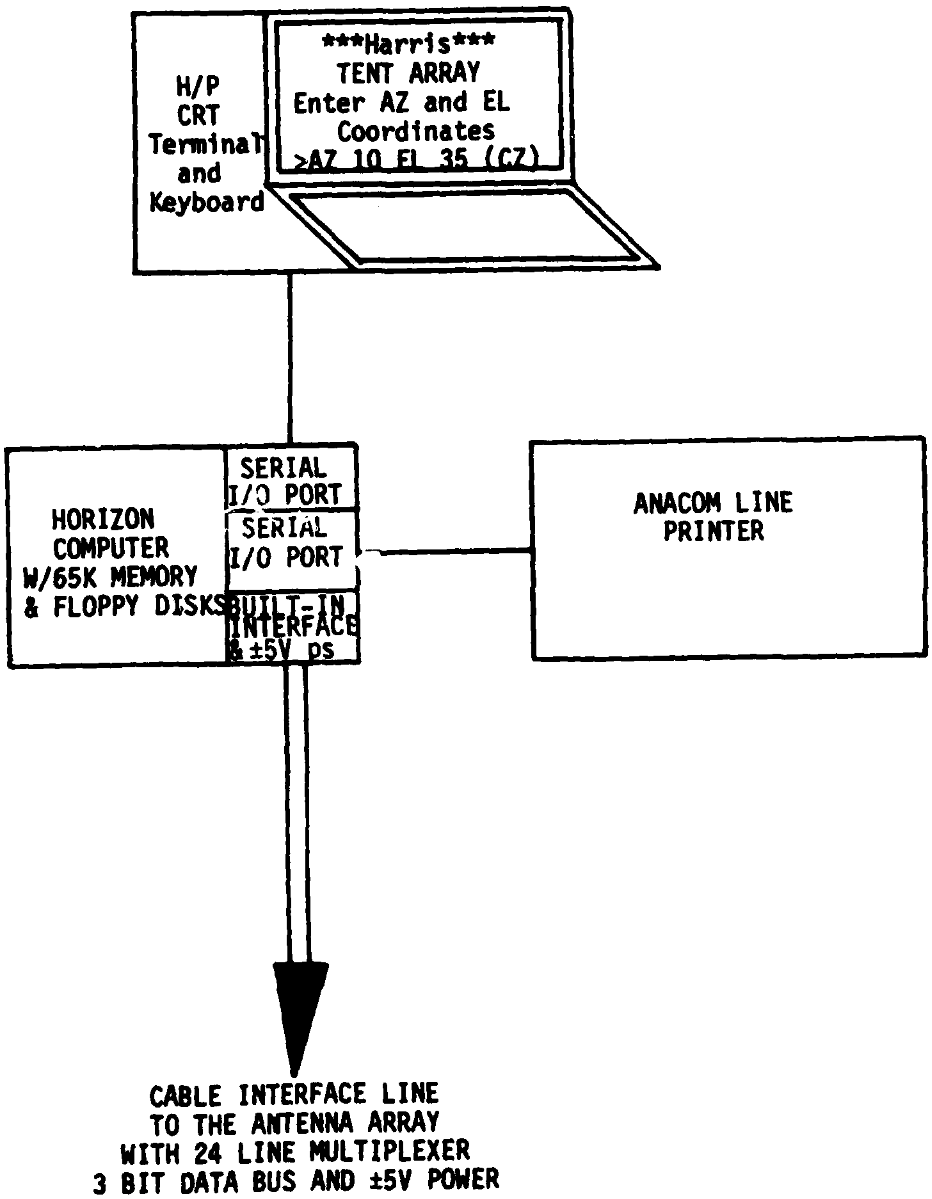
REQUIREMENTS DOCUMENTATION

DATA REQUIREMENTS OVERVIEW

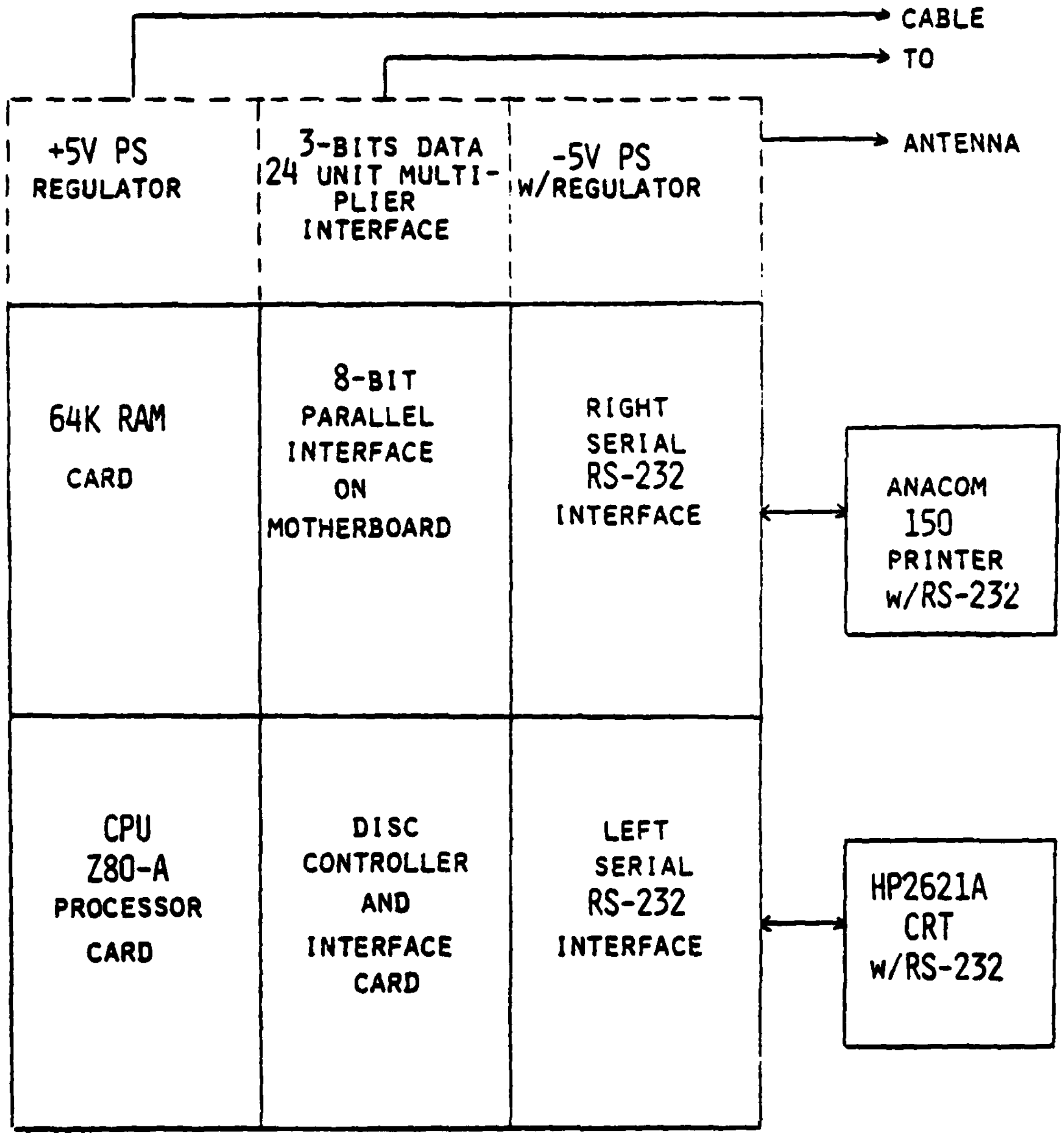
The data base of critical importance to this system is the list of 24 phase shifter value codes that set the beam to a particular azimuth and elevation position. There are 15 azimuth positions and 15 elevation positions resulting in a matrix of 225 positions. Each of these positions has associated with it the 24 phase shifter values. Thus the data is arranged into an array called SHIFTERDATA (AZIMUTH, ELEVATION, SHIFTER) where AZIMUTH = 0..14 and ELEVATION = 0..14 and SHIFTER = 1..24. This is written to a file of bytes on the floppy disc. The second data base in the program is for storing the row and column separations of the antenna elements during the CALCULATE ROUTINE. These are designed into two arrays of Index 1 to 24 and are initialized within the procedure.

TENT ARRAY CONTROLLER

DIAGRAM



BLOCK DIAGRAM OF HARDWARE DESIGN APPROACH



CONTROLLER SPECIFICATIONS

	NORTHSTAR HORIZON	HP2621A CRT	ANACOM 150 PRINTER	CONTROLLER SYSTEM
SIZE (L X H X D)	20" x 8" x 18"	15" x 17.5" x 18.5"	23" x 8" x 16"	38" x 17.5" x 18.
POWER (120v)	410W(3.4A)	50W(0.4A)	140W(1.16A)	600W(5A)
WEIGHT (NET.)	44 LBS	32 LBS	34 LBS	110 LBS
TEMPERATURE	4°C TO 38°C	0°C TO 55°C	4°C TO 35°C	4°C TO 35°C (40°F TO 95°F)
T/HR.	5°C/HR	10°C/HR	10°C/HR	5°C/HR
ALTITUDE	0 - 6,000 FT.	0 - 15,000 FT	0 - 40,000 FT	0 - 6,000 FT
RELATIVE HUMIDITY (NON-CONDENSING)	20% TO 80%	5% TO 95%	10% TO 80%	20% TO 80%
BAND RATE	9600 MAX	9600 MAX	9600 MAX	9600 MAX

PERFORMANCE VS. SPECIFICATION

An antenna interface simulator has been constructed and tested allowing the display of all 24 phase shifter values. The simulator tests the hardware interface circuit and cable as well as allowing visual checks on the software performance. Through the antenna phase shifter simulator all hardware and software interactions have been tested and debugged.

PROBLEM AREAS AND PROPOSED RESOLUTIONS

The initial phase shifter values are the highest risk area. The mechanical and electrical tolerances will cause phase variations from channel to channel, increasing the uncertainty. Adjusting the phase shifter feed line lengths is proposed although the method is expensive. The software table editor has been designed to allow optimization of the phase shifter values in the most efficient manner possible.

TENT ARRAY CONTROLLER
FEATURES

INTERACTIVE TERMINAL

- H/P 2621A WITH RS232C 9600 BAUD COMMUNICATION.
- CLEAR 24 LINE, 80 CHARACTER DISPLAY WITH EMBEDDED CALCULATOR-STYLE NUMERIC KEY PAD.
- CONFIGURATION MEMORY PROTECTION AND SELF-TEST.

DOT MATRIX PRINTER

- ANACOM 150 WITH RS232C 9600 BAUD COMMUNICATION.
- HOLD, RESET, STEP AND FORM FEED FUNCTIONS.
- PARALLEL OPERATION WITH TERMINAL AND SELF-TEST MODES.

COMPUTER CONTROLLER

- NORTHSTAR HORIZON SYSTEM.
- 64K DYNAMIC MEMORY.
- 330K NON-VOLATILE MASS STORAGE ON TWO DOUBLE DENSITY FLOPPY DISCS.
- INTERFACE TO ARRAY AND ±5V POWER TO THE ARRAY ARE INCLUDED IN THE PACKAGE.

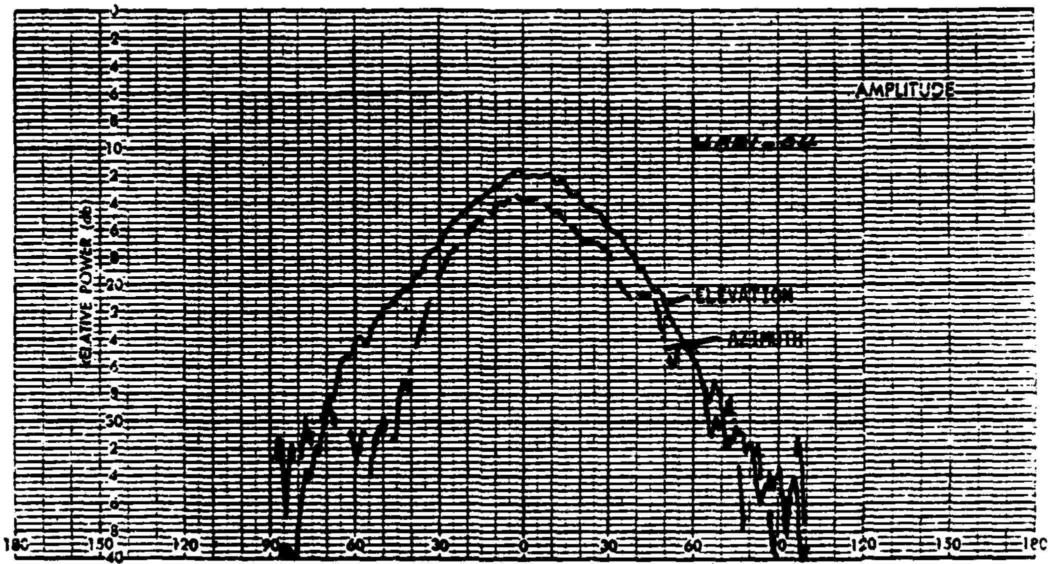
SYSTEM SOFTWARE

- PASCAL HIGH-LEVEL LANGUAGE USED WITH MODULAR TOP-DOWN DESIGN APPROACH.
- CONTROL PROGRAM/MICROPROCESSOR (CP/M) OPERATING SYSTEM USED FOR MACHINE-INDEPENDENT OPERATION.

APPENDIX B

ANTENNA PATTERNS

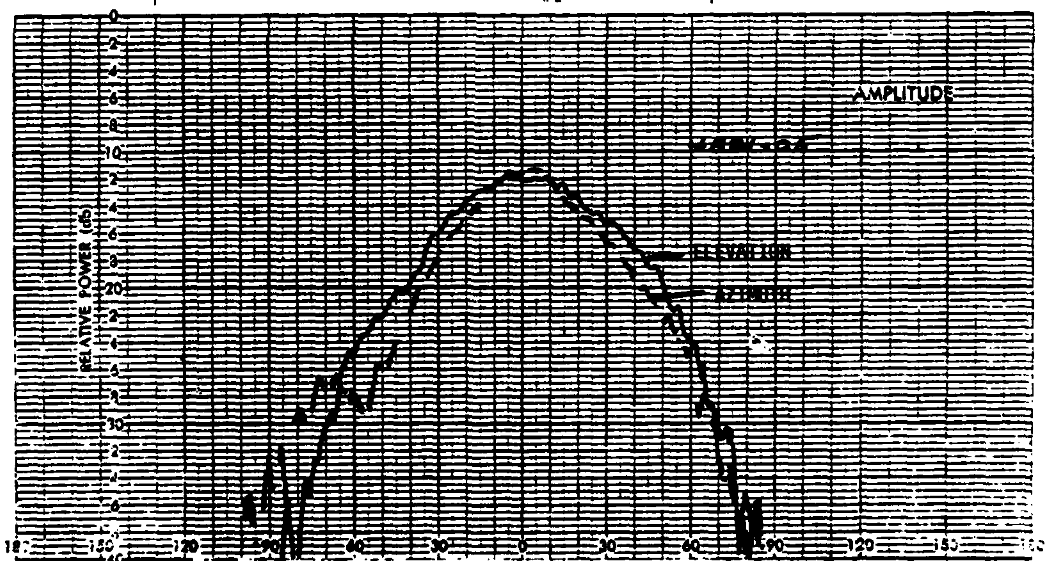
FIGURES B1 - B12:	ACTIVE ELEMENT PATTERNS
FIGURES B13 - B34:	SCANNING PATTERNS



PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE
ELEMENT
PATTERNS
#1

HARRIS

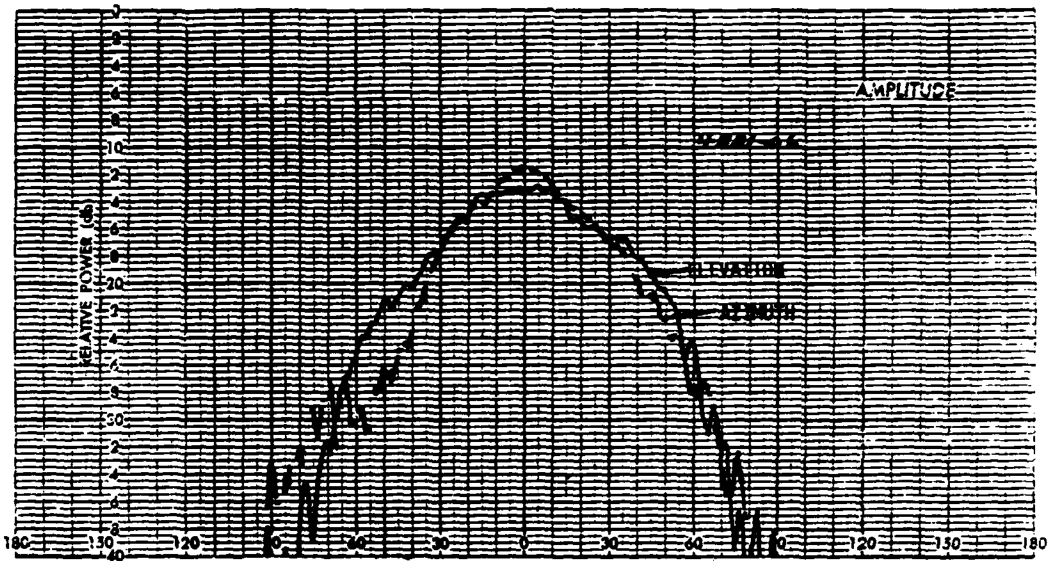


PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE
ELEMENT
PATTERNS
#2

HARRIS

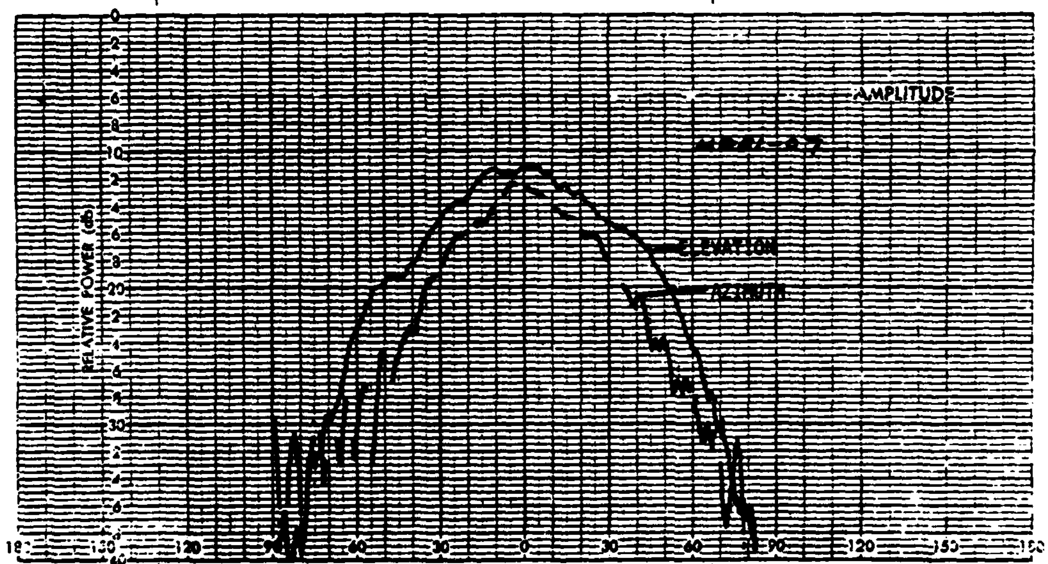
FIGURE B-1



PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE ELEMENT PATTERNS #3

HARRIS

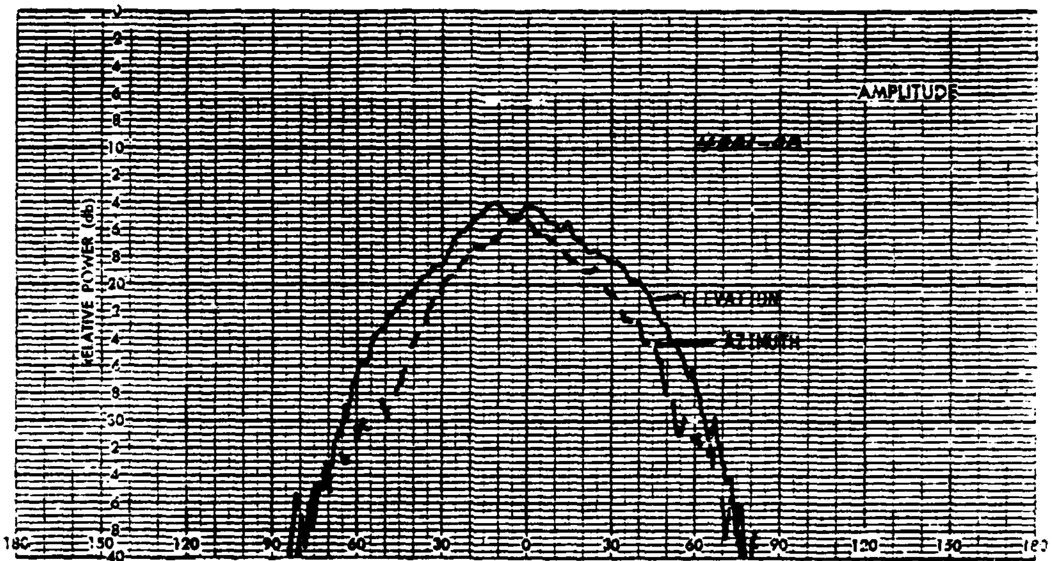


PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE ELEMENT PATTERNS #4

HARRIS

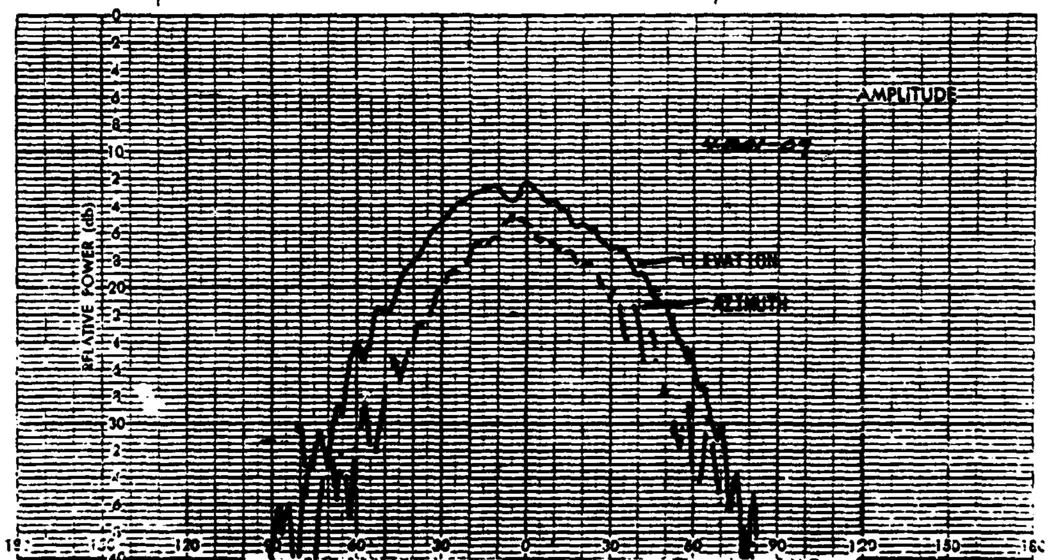
FIGURE B-2



PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE ELEMENT PATTERNS #5

HARRIS
ELECTRONIC SYSTEMS DIVISION

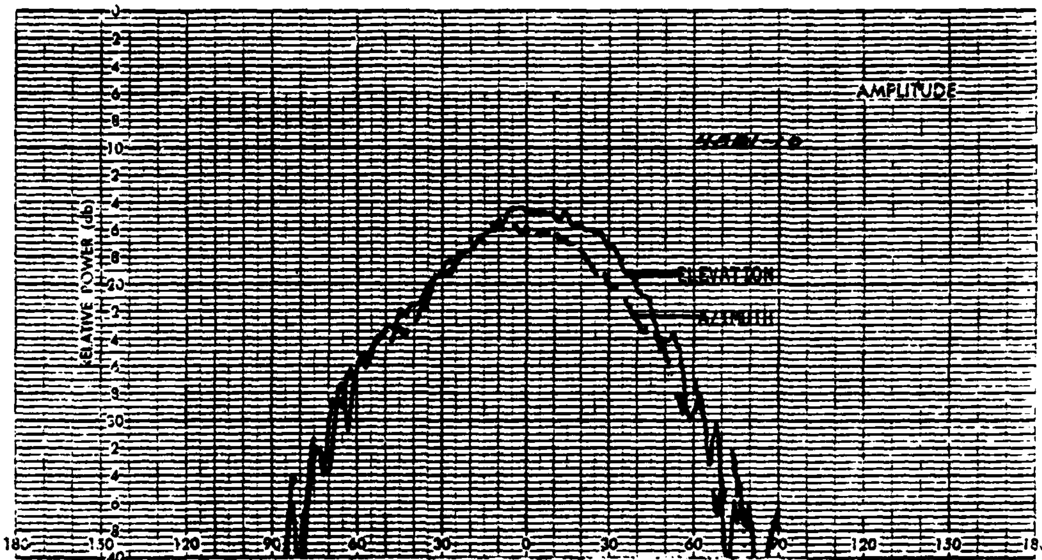


PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE ELEMENT PATTERNS #6

HARRIS
ELECTRONIC SYSTEMS DIVISION

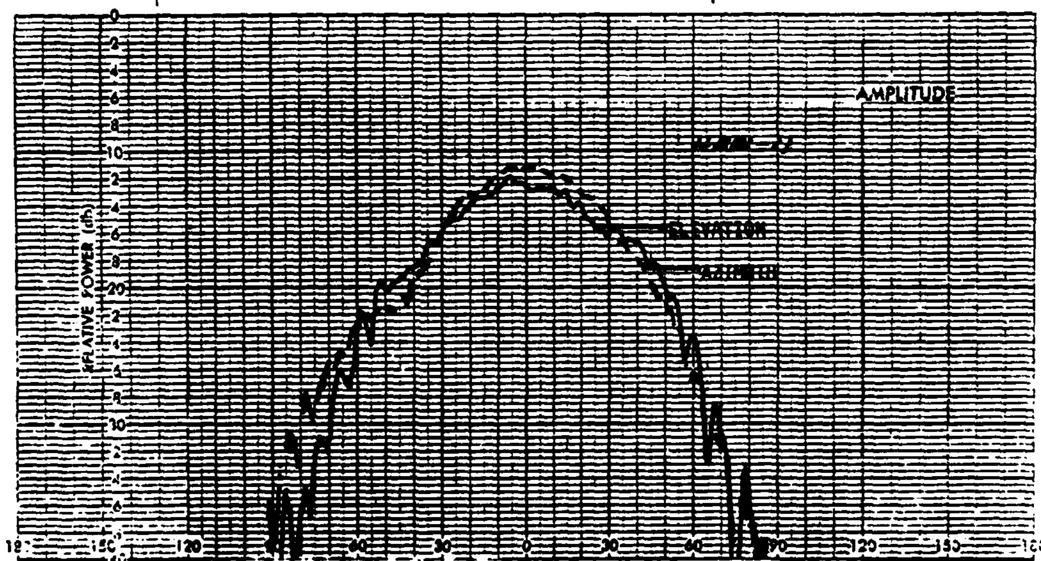
FIGURE B-3



PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE
ELEMENT
PATTERNS
#7

HARRIS
ELECTRONIC SYSTEMS DIVISION

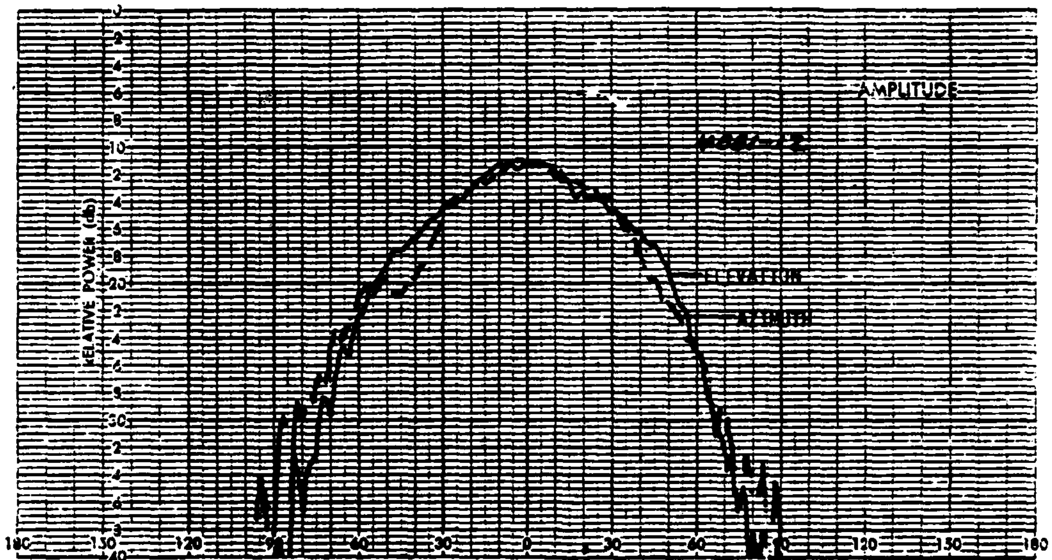


PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE
ELEMENT
PATTERNS
#8

HARRIS
ELECTRONIC SYSTEMS DIVISION

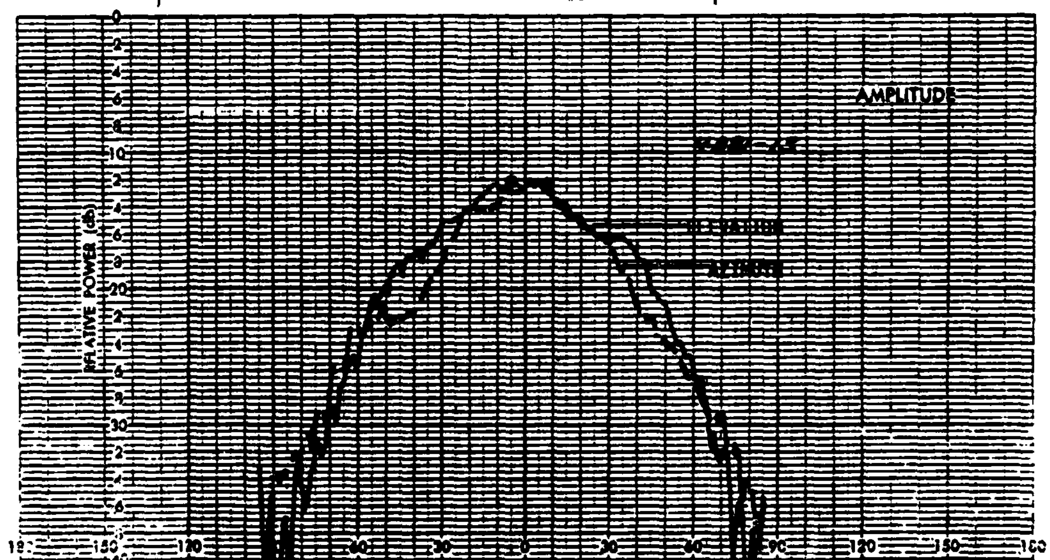
FIGURE B-4



PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE ELEMENT PATTERNS #9

HARRIS

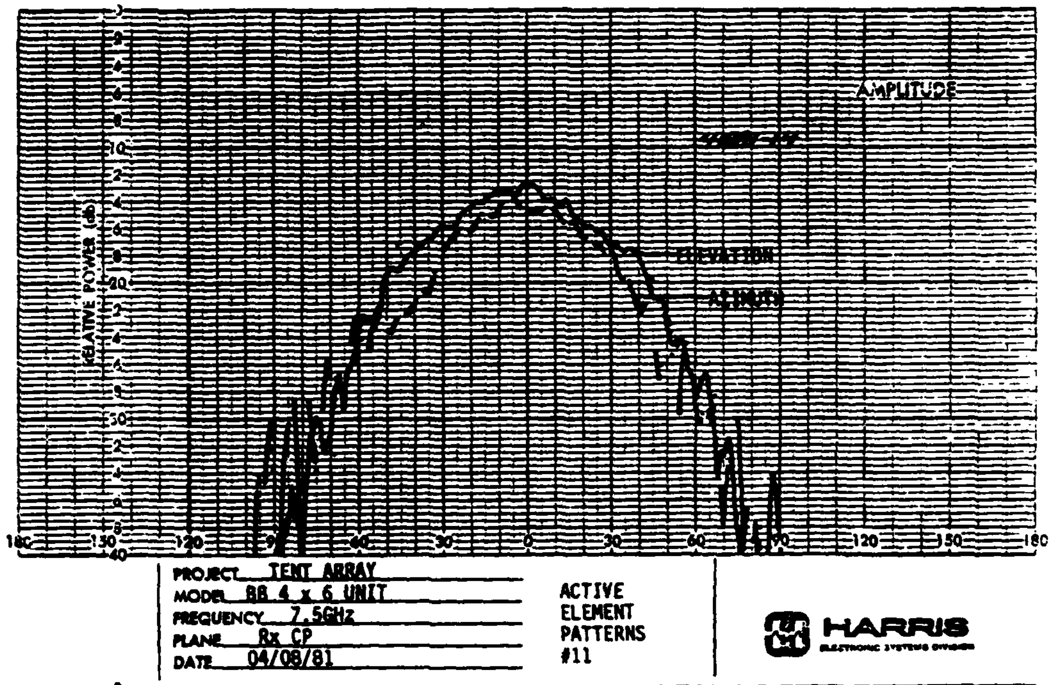


PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE ELEMENT PATTERNS #10

HARRIS

FIGURE B-5


AMPLITUDE
ELEVATION
AZIMUTH
RELATIVE POWER (dB)
PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81
ACTIVE
ELEMENT
PATTERNS
#11
HARRIS

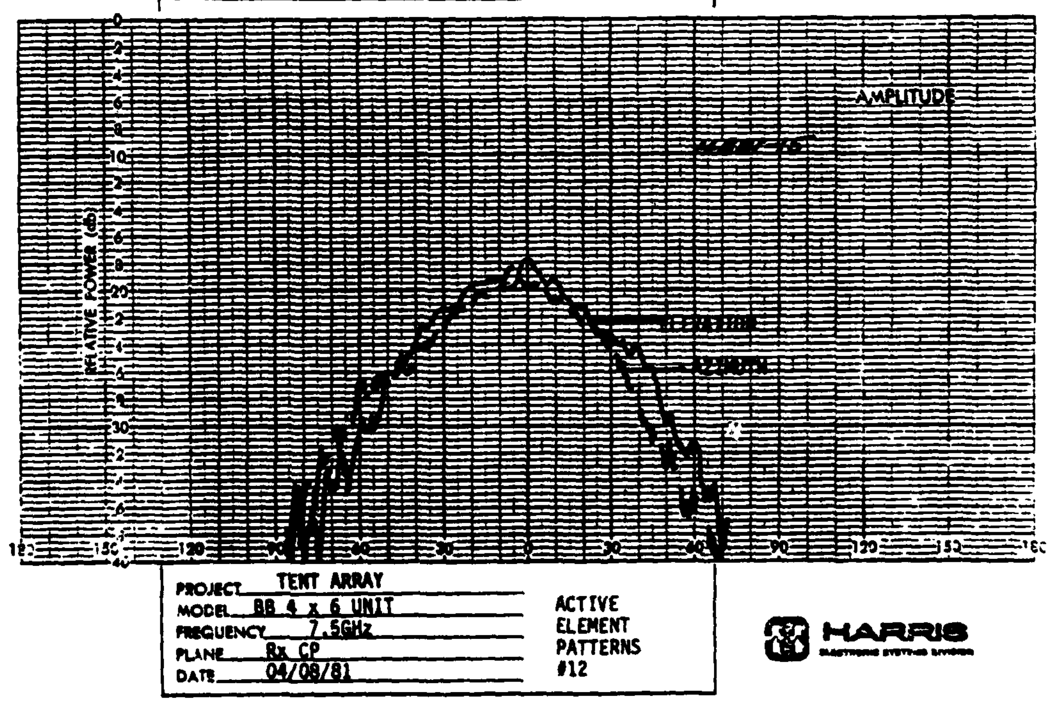
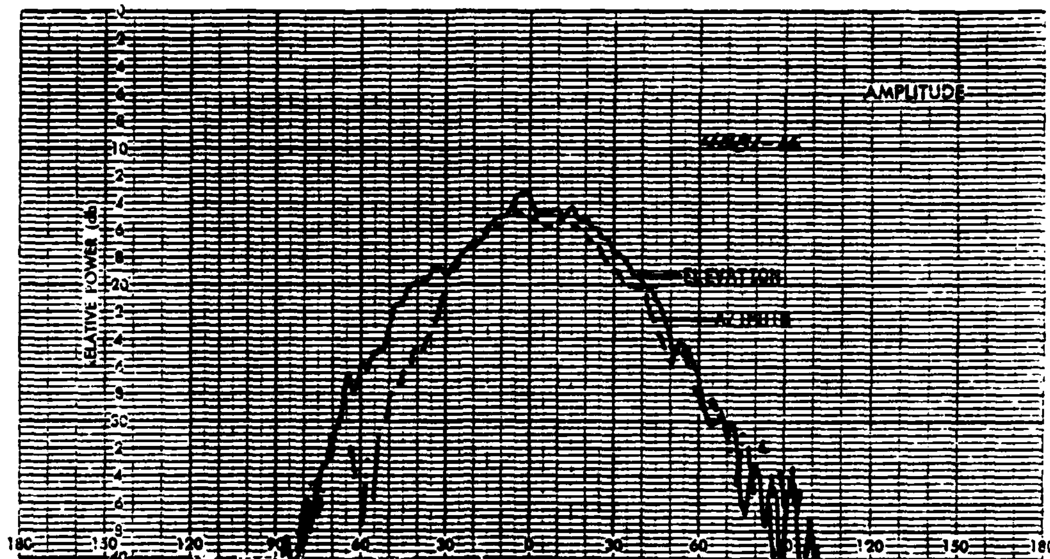

AMPLITUDE
ELEVATION
AZIMUTH
RELATIVE POWER (dB)
PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81
ACTIVE
ELEMENT
PATTERNS
#12
HARRIS

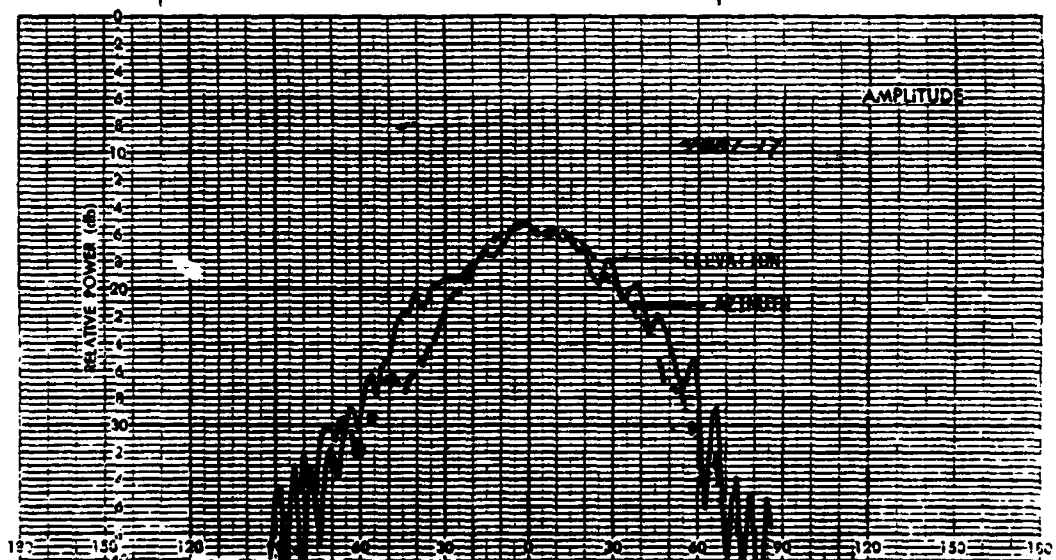
FIGURE B-6



PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE
ELEMENT
PATTERNS
#13

HARRIS
ELECTRONIC SYSTEMS DIVISION

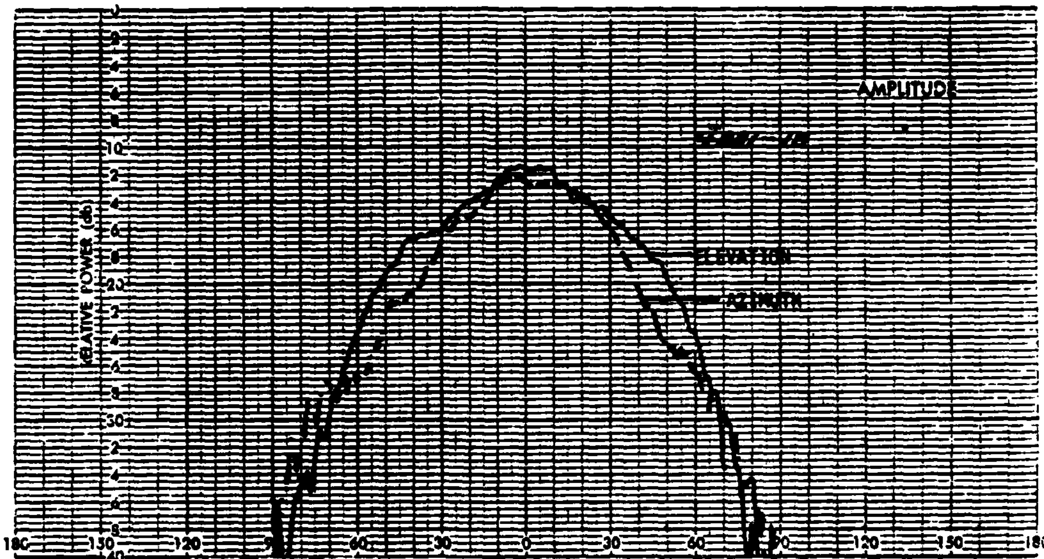


PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE
ELEMENT
PATTERNS
#14

HARRIS
ELECTRONIC SYSTEMS DIVISION

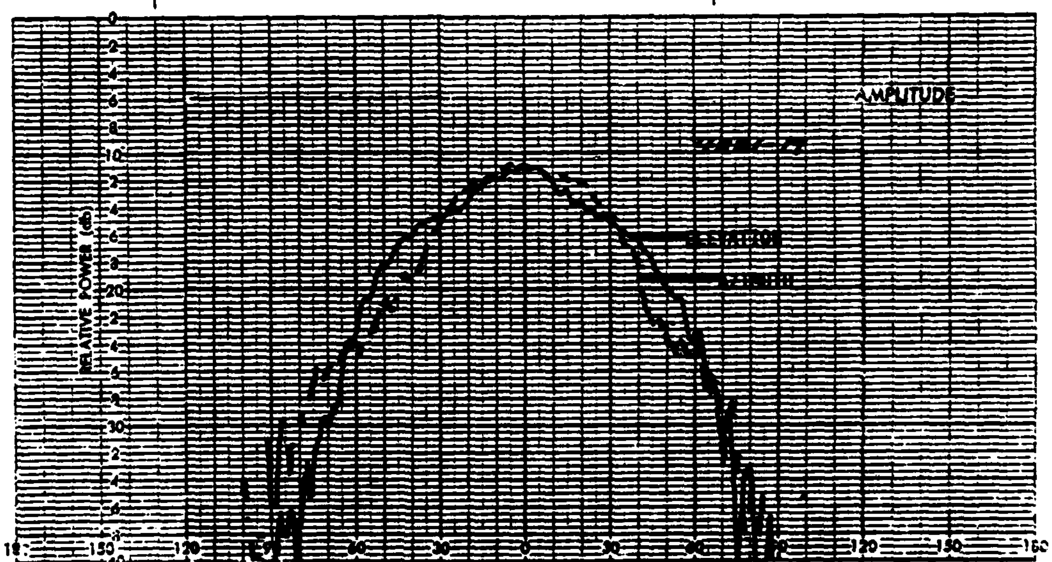
FIGURE B-7



PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE ELEMENT PATTERNS #15

HARRIS ELECTRONIC SYSTEMS DIVISION

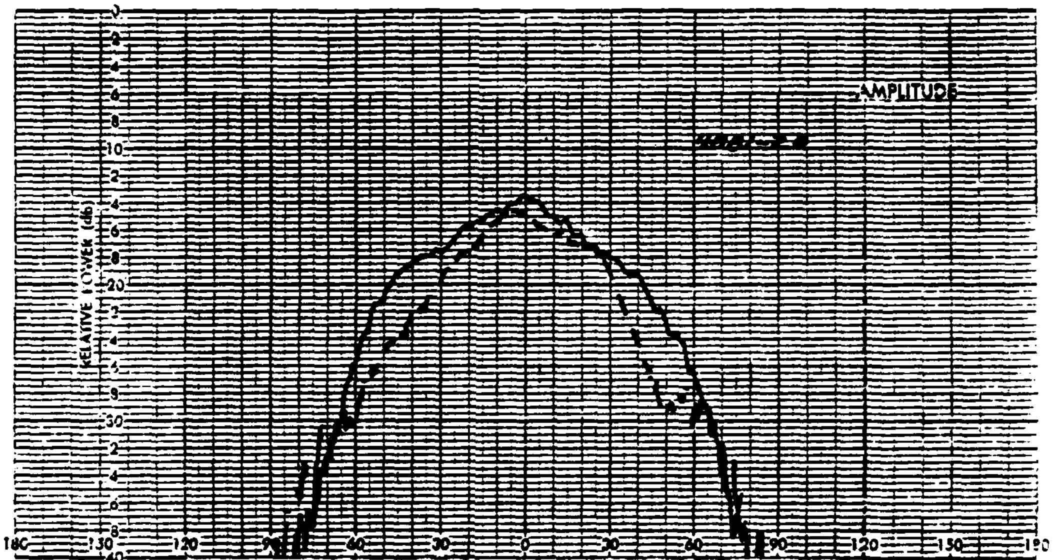


PROJECT TENT ARRAY
MODEL BB 4 x 6 UNIT
FREQUENCY 7.5GHz
PLANE Rx CP
DATE 04/08/81

ACTIVE ELEMENT PATTERNS #16

HARRIS ELECTRONIC SYSTEMS DIVISION

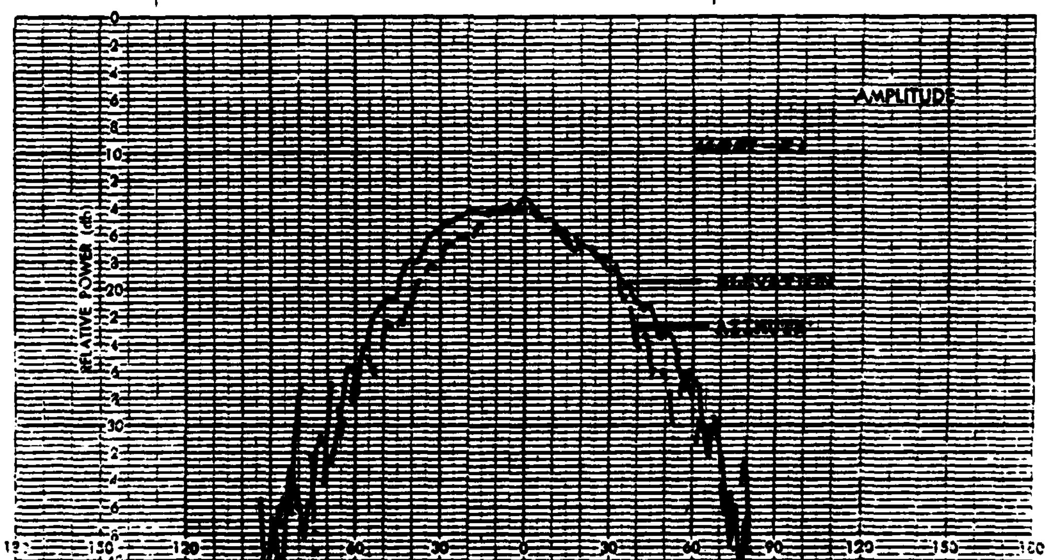
FIGURE B-8



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE Rx CP
DATE 4/1/81

ACTIVE ELEMENT PATTERNS #17

HARRIS

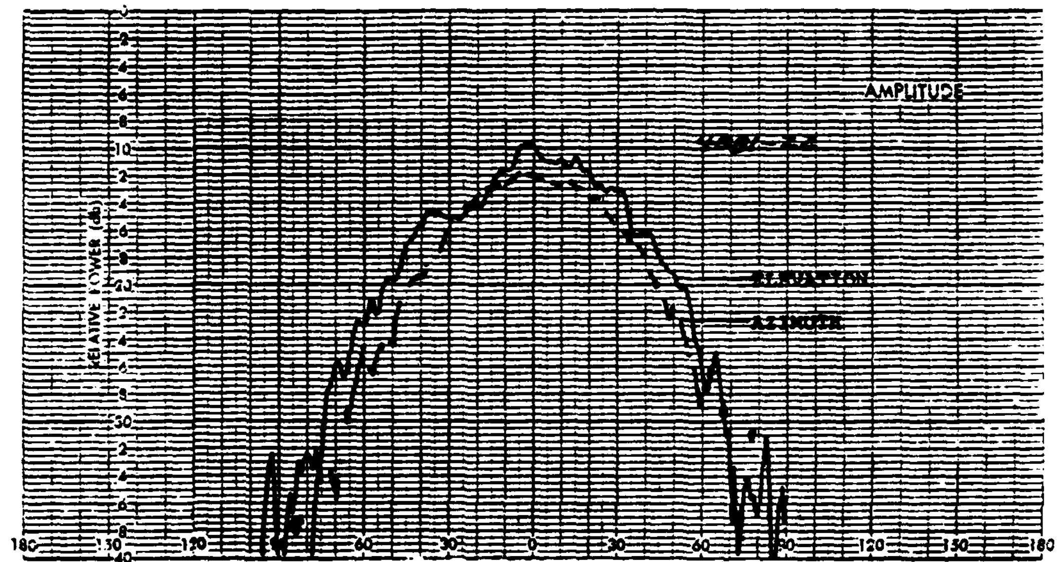


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE Rx CP
DATE 4/8/81

ACTIVE ELEMENT PATTERNS #18

HARRIS

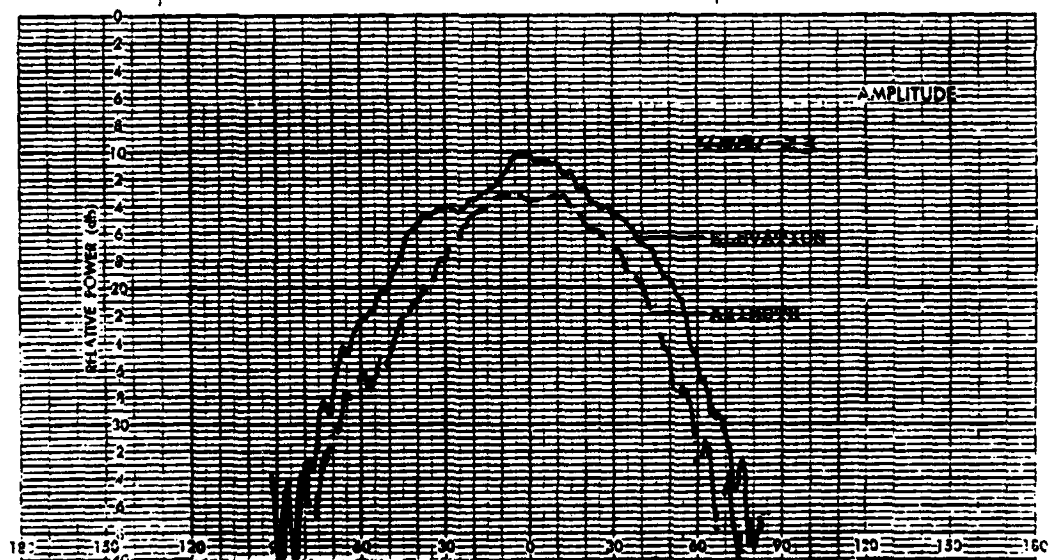
FIGURE B-9



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE Rx CP
DATE 4/8/81

ACTIVE ELEMENT PATTERNS #19

HARRIS

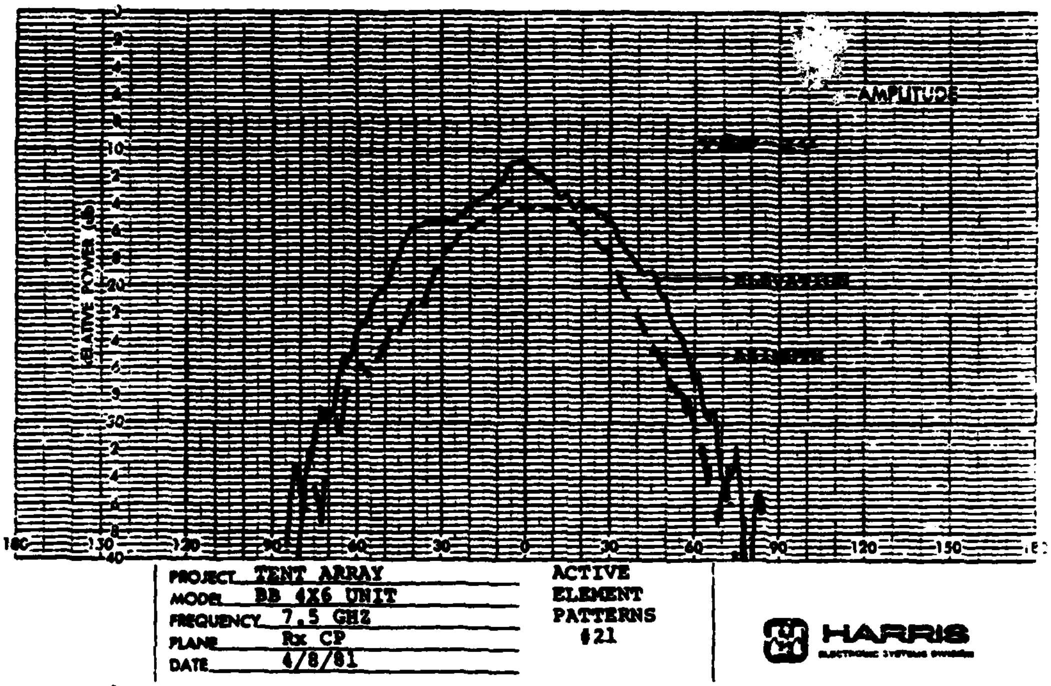


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE Rx Cp
DATE 4/8/81

ACTIVE ELEMENT PATTERNS #20

HARRIS

FIGURE B-10


AMPLITUDE
RELATIVE POWER (dB)
PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE Rx CP
DATE 4/8/81
ACTIVE ELEMENT PATTERNS #21
HARRIS

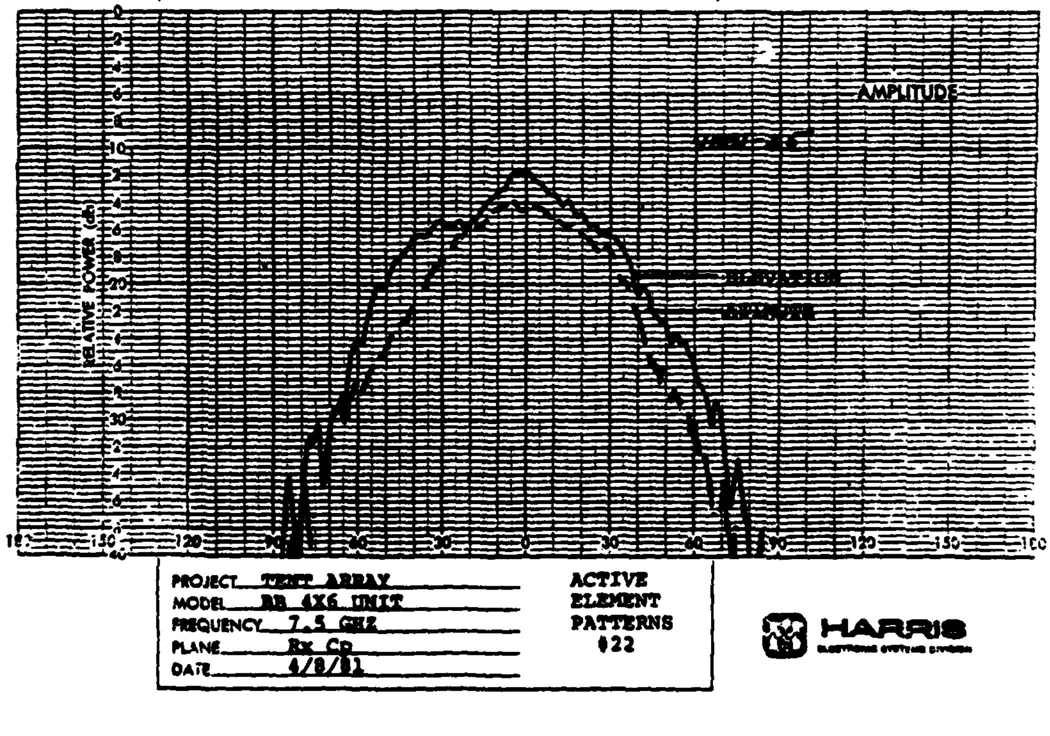
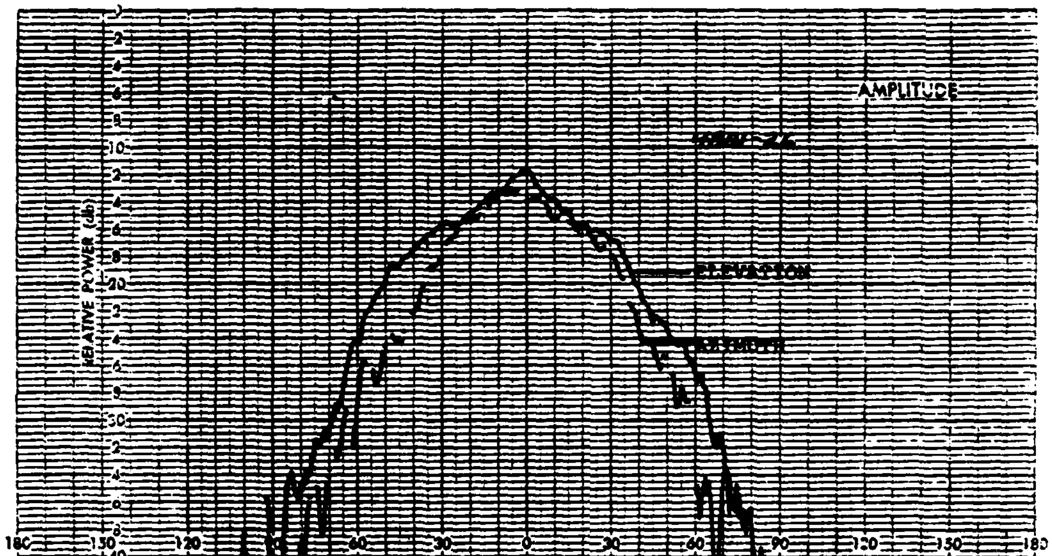

AMPLITUDE
RELATIVE POWER (dB)
PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE Rx Cp
DATE 4/8/81
ACTIVE ELEMENT PATTERNS #22
HARRIS

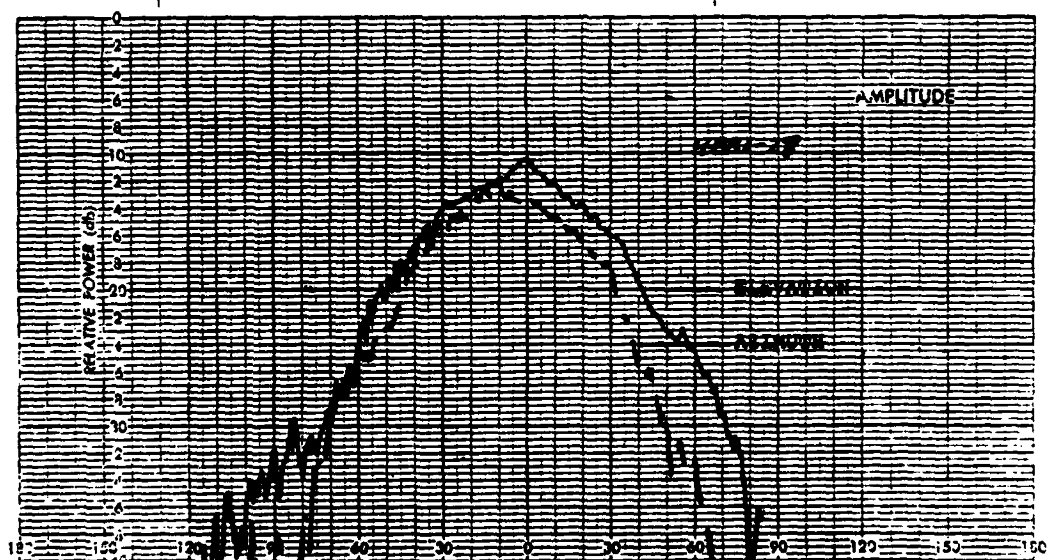
FIGURE B-11



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE Rx CP
DATE 4/8/81

ACTIVE ELEMENT PATTERNS #23

HARRIS ELECTRONIC SYSTEMS DIVISION

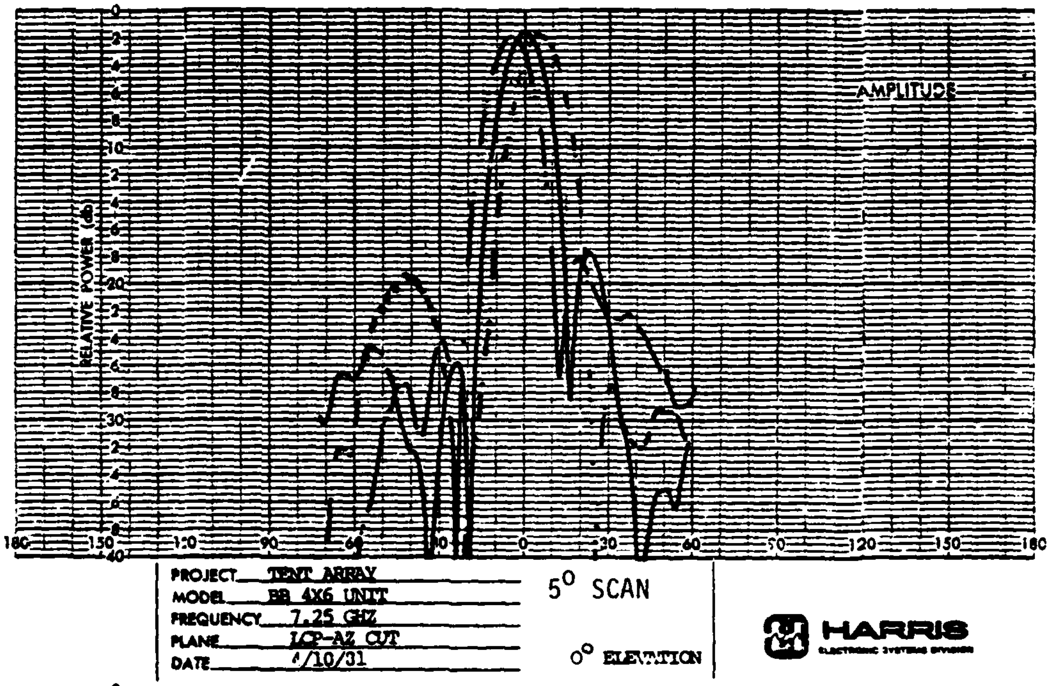


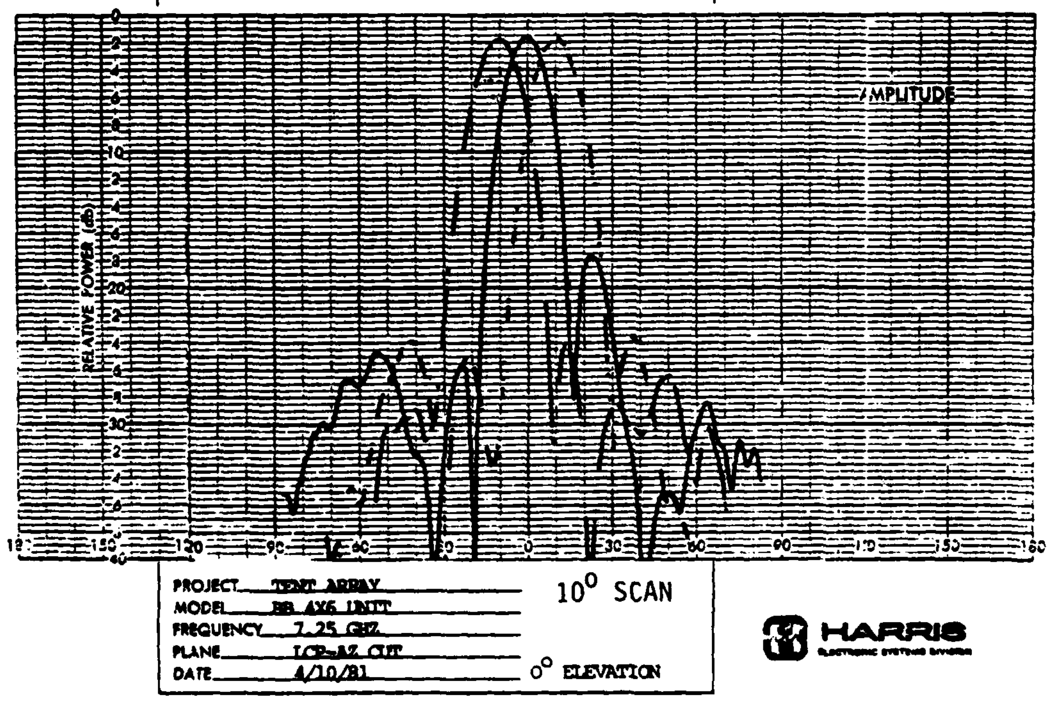
PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE Rx CP
DATE 4/8/81

ACTIVE ELEMENT PATTERNS #24

HARRIS ELECTRONIC SYSTEMS DIVISION

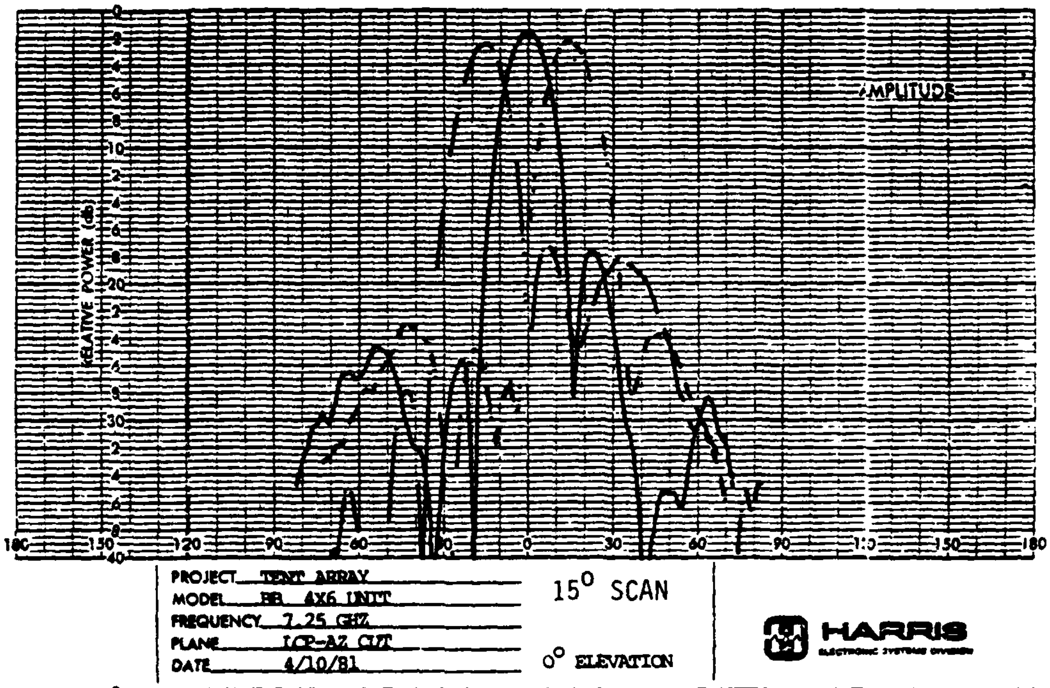
FIGURE B-12

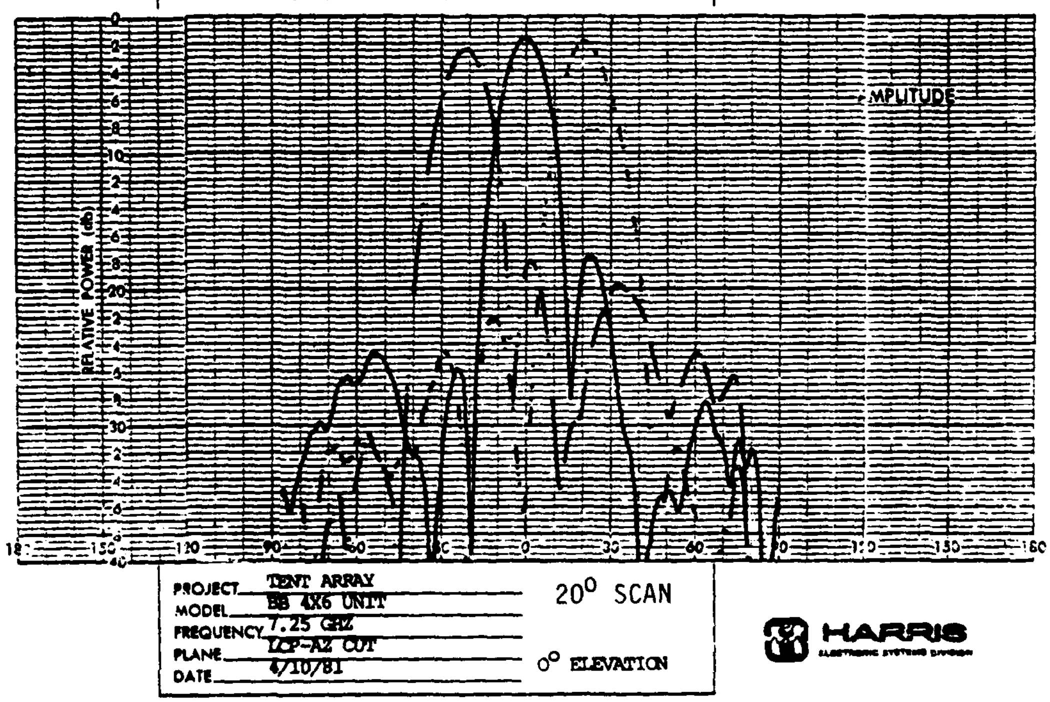




AZIMUTH SCAN ARRAY PATTERNS

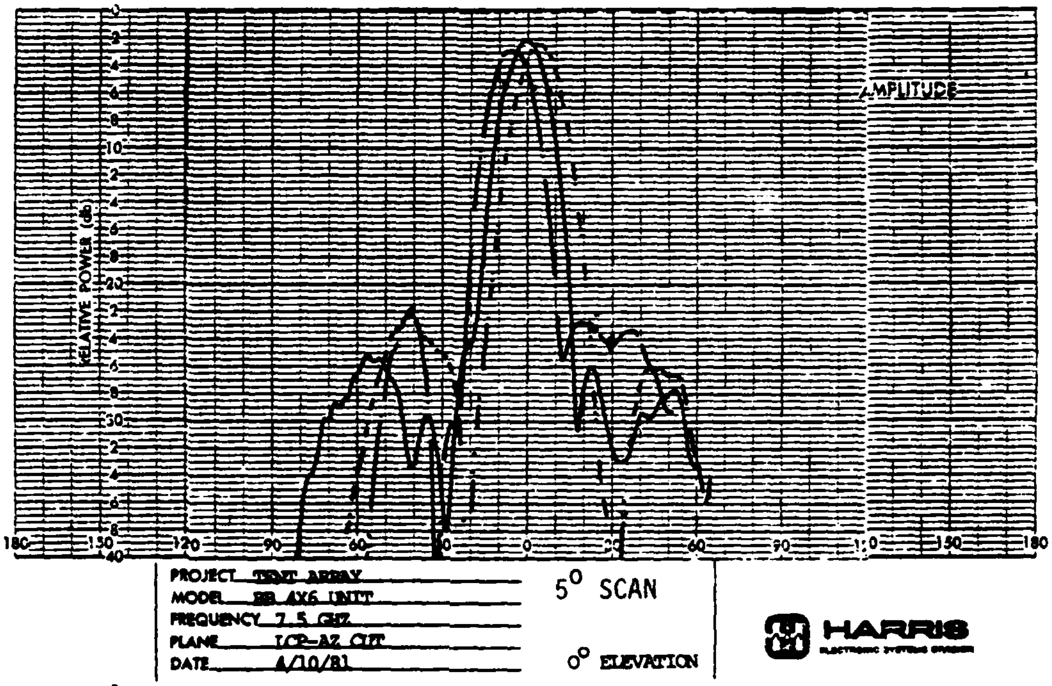
FIG. B-13

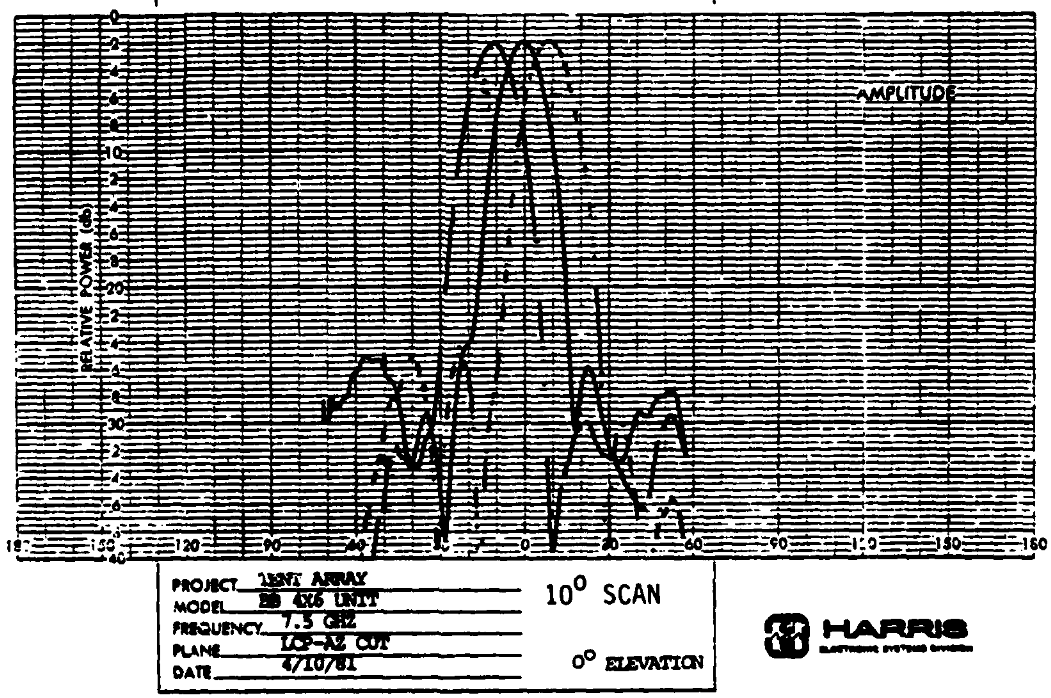




AZIMUTH SCAN ARRAY PATTERNS

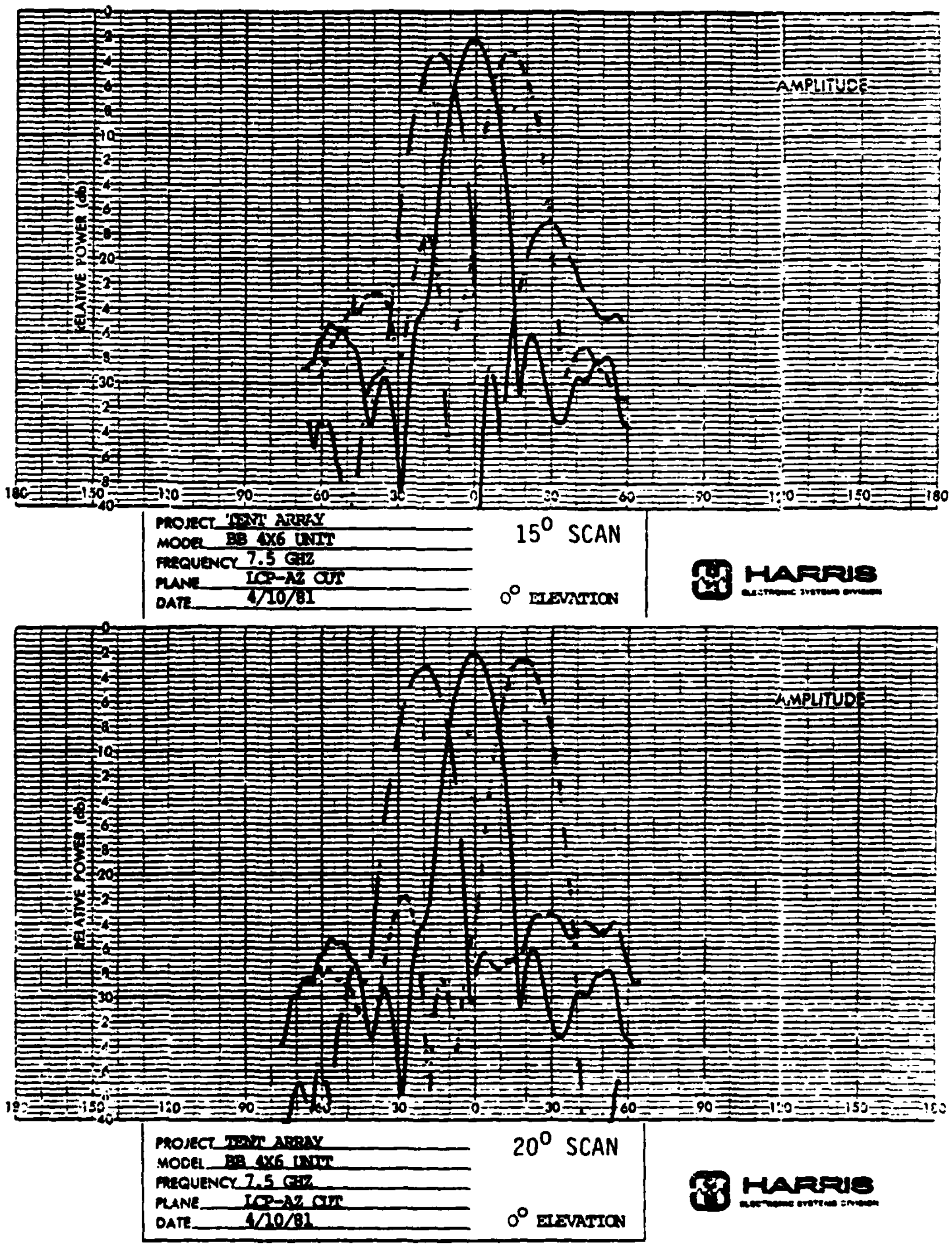
FIG. B-14





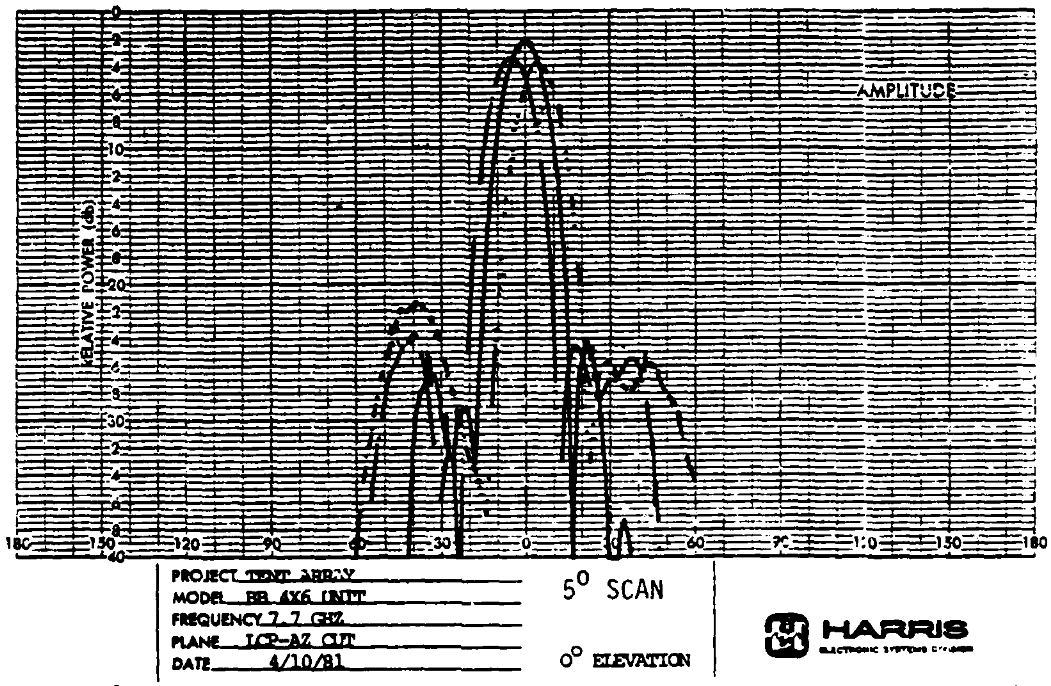
AZIMUTH SCAN ARRAY PATTERNS

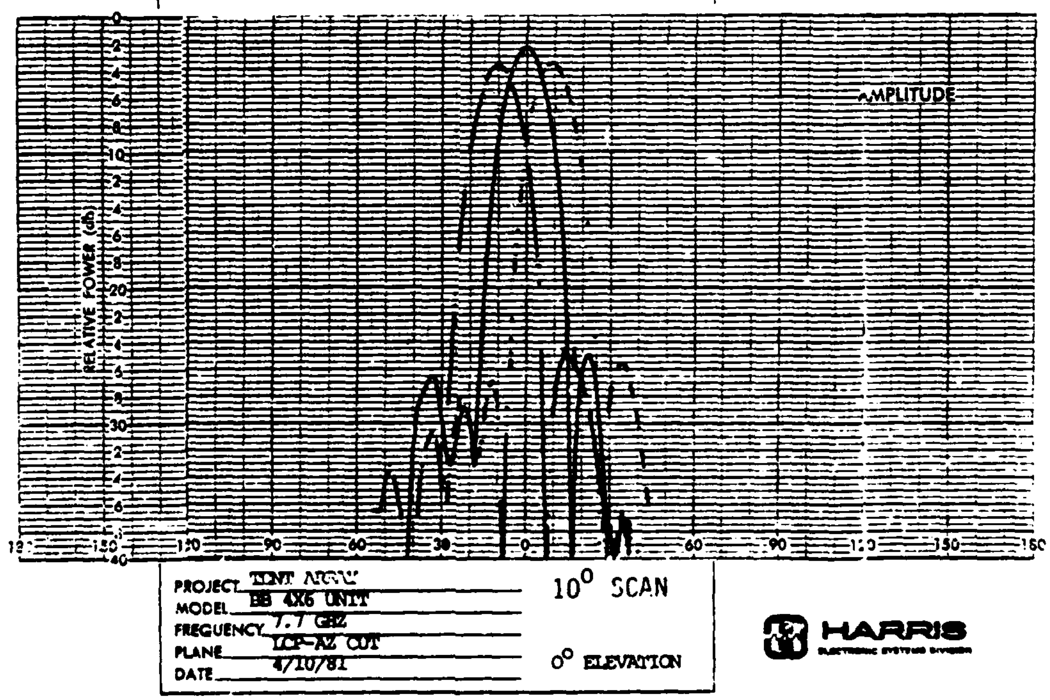
FIG. B-15



AZIMUTH SCAN ARRAY PATTERNS

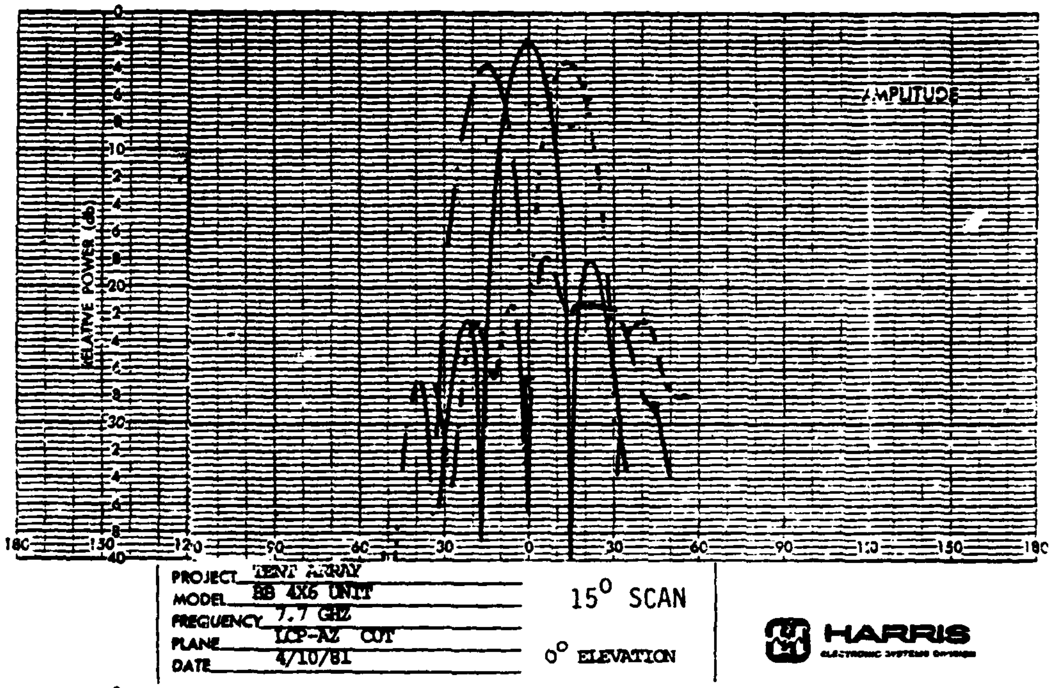
FIG. B-16

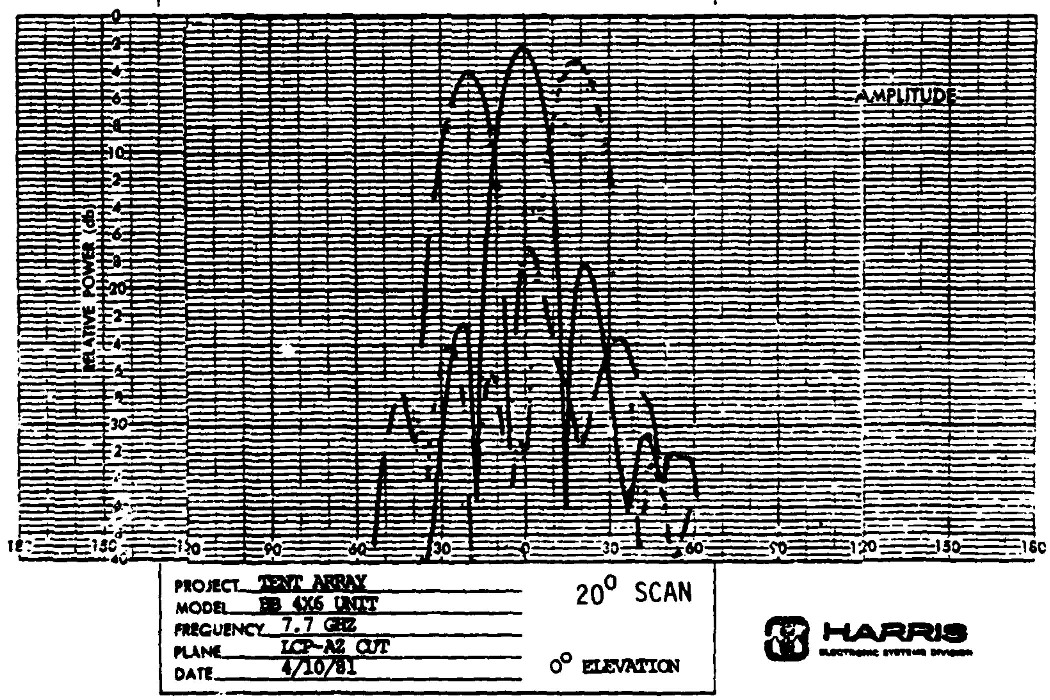




AZIMUTH SCAN ARRAY PATTERNS

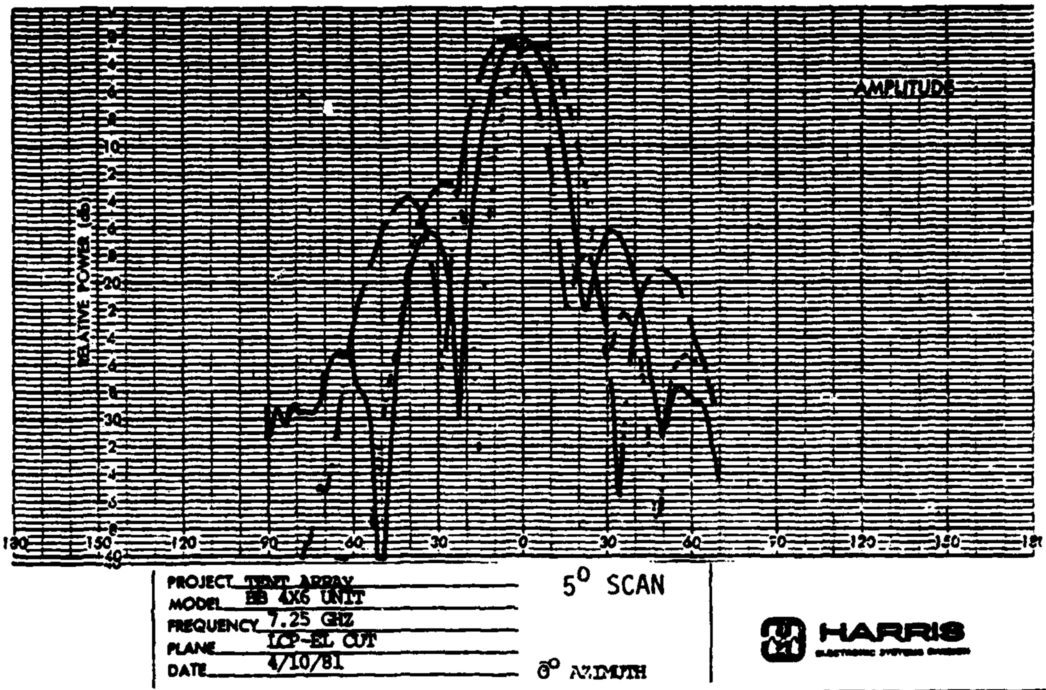
FIG. B-17

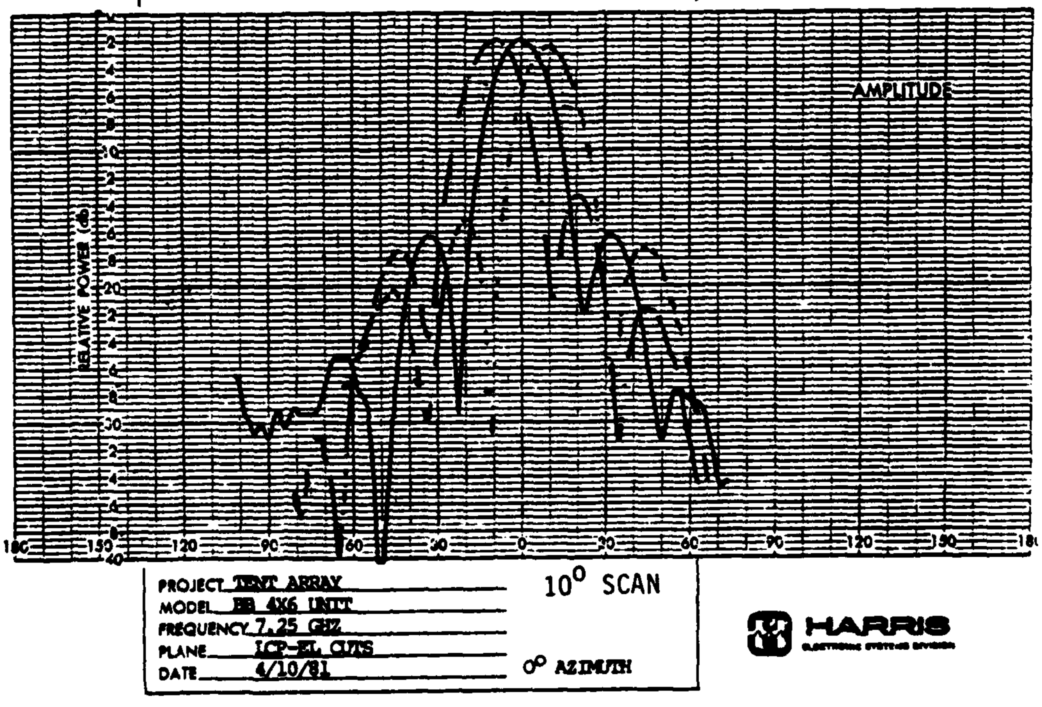




AZIMUTH SCAN ARRAY PATTERNS

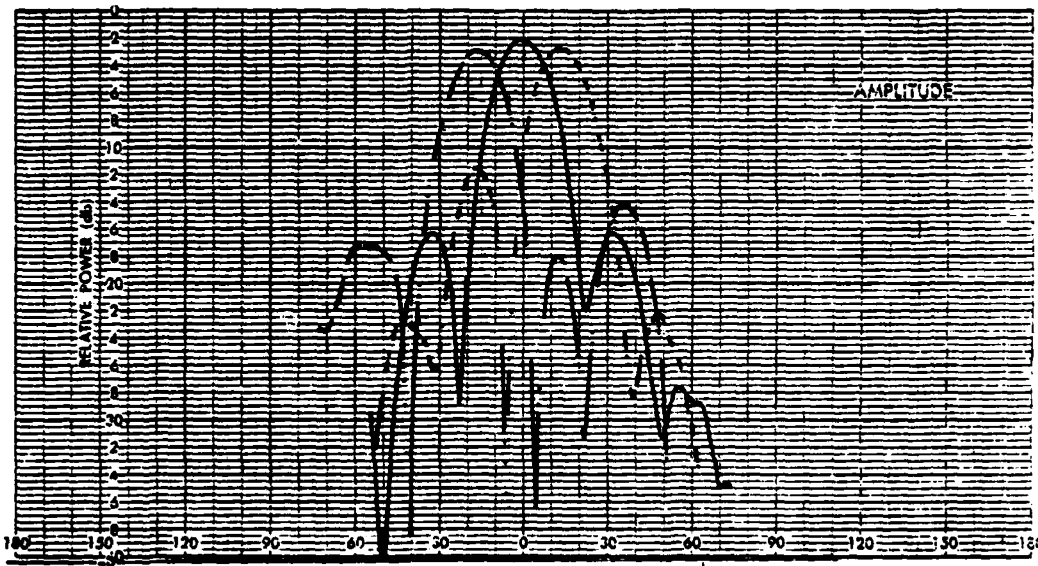
FIG. B-18





ELEVATION SCAN ARRAY PATTERNS

FIG. B-19

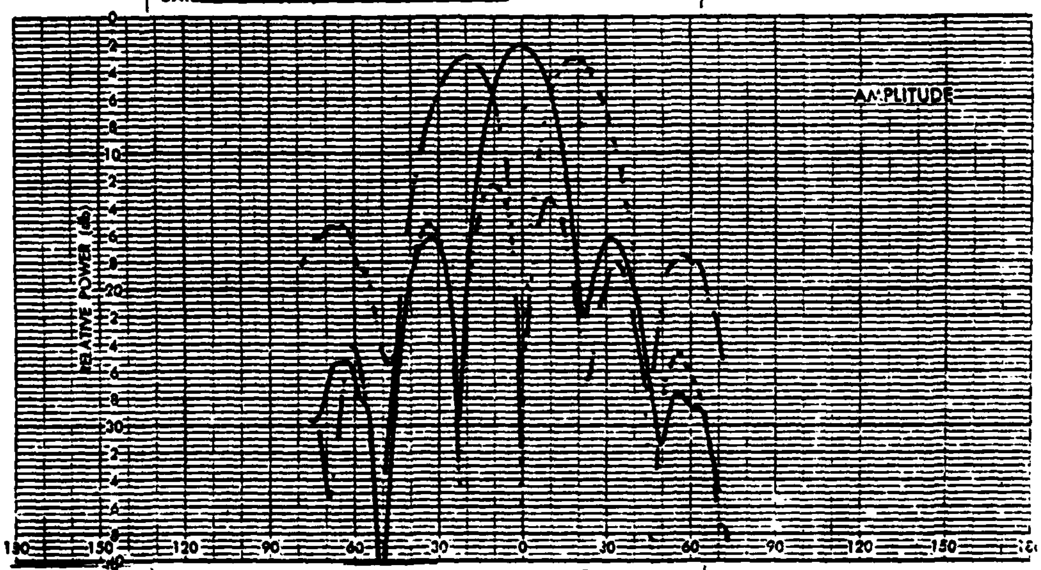


PROJECT TENT ARRAY
MODEL BB4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE LCP-EL CUT
DATE 4/10/81

15° SCAN

0° AZIMUTH

HARRIS



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE LCP-EL CUT
DATE 4/10/81

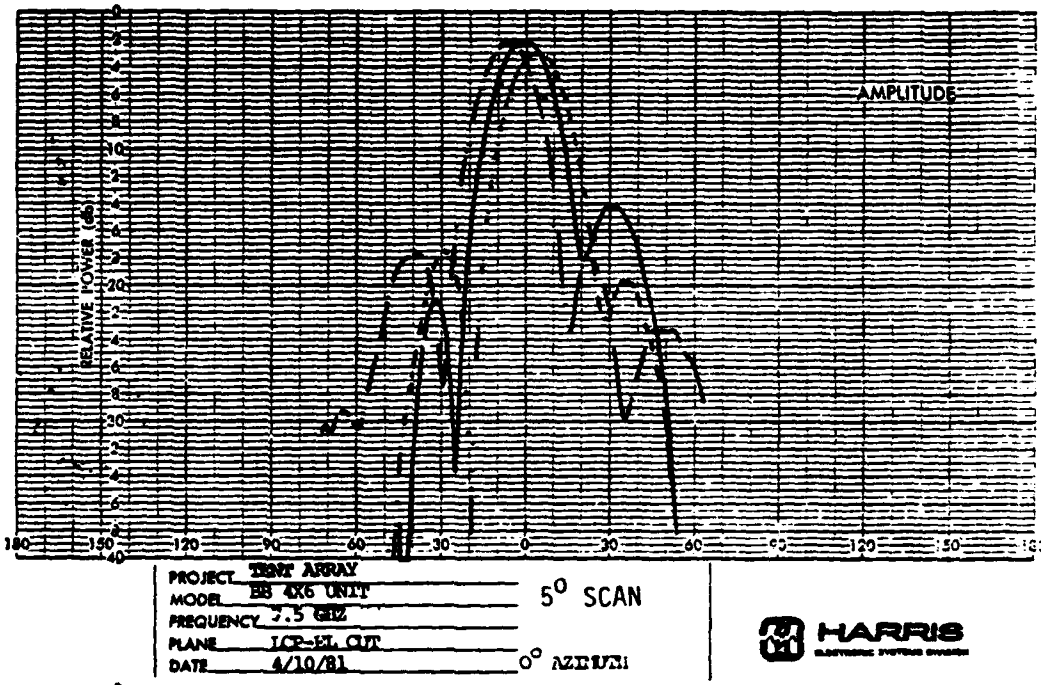
20° SCAN

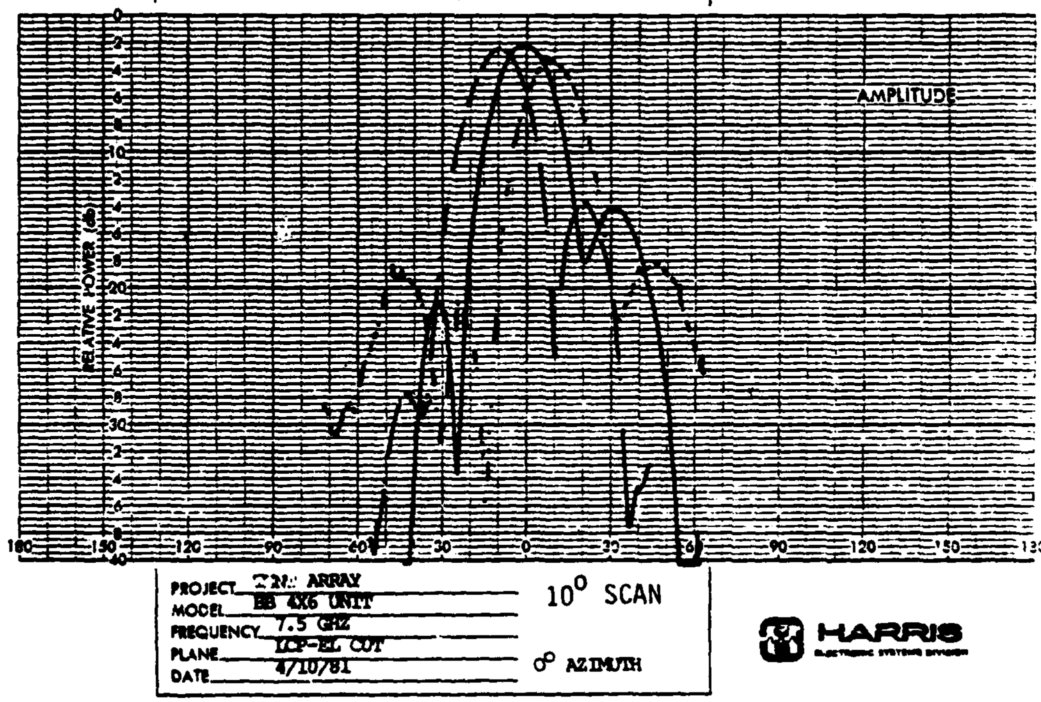
0° AZIMUTH

HARRIS

ELEVATION SCAN ARRAY PATTERNS

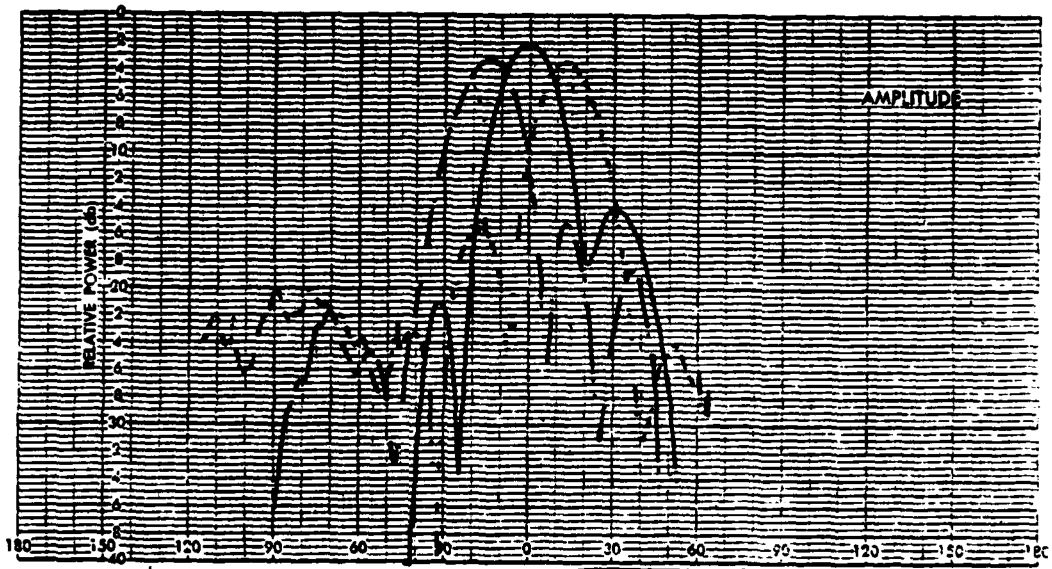
FIG. B-20





ELEVATION SCAN ARRAY PATTERNS

FIG. B-21

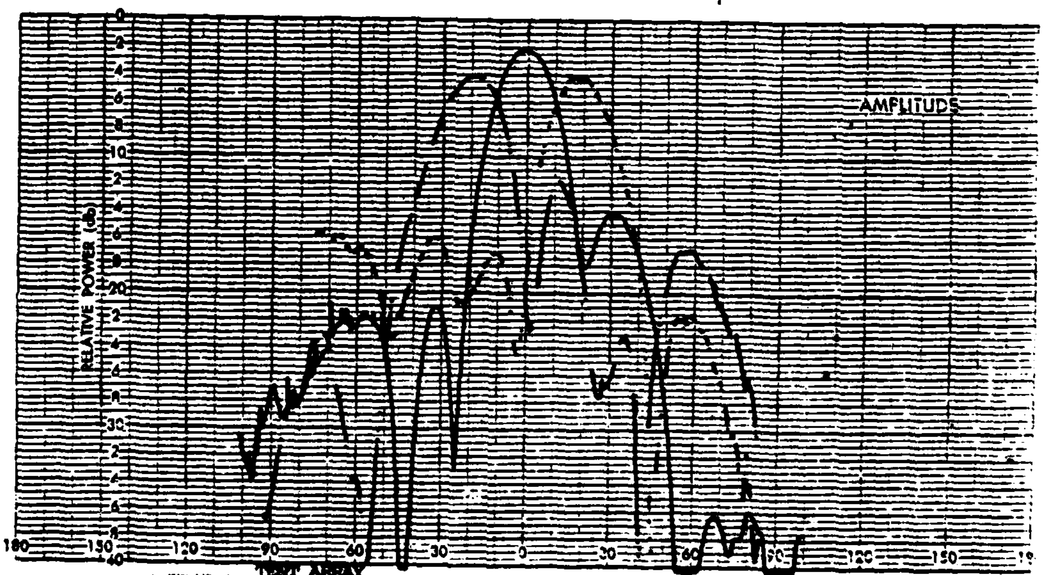


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE LCP-EL CUT
DATE 4/10/81

15° SCAN

0° AZIMUTH

HARRIS ELECTRONIC SYSTEMS DIVISION



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE LCP-EL CUT
DATE 4/10/81

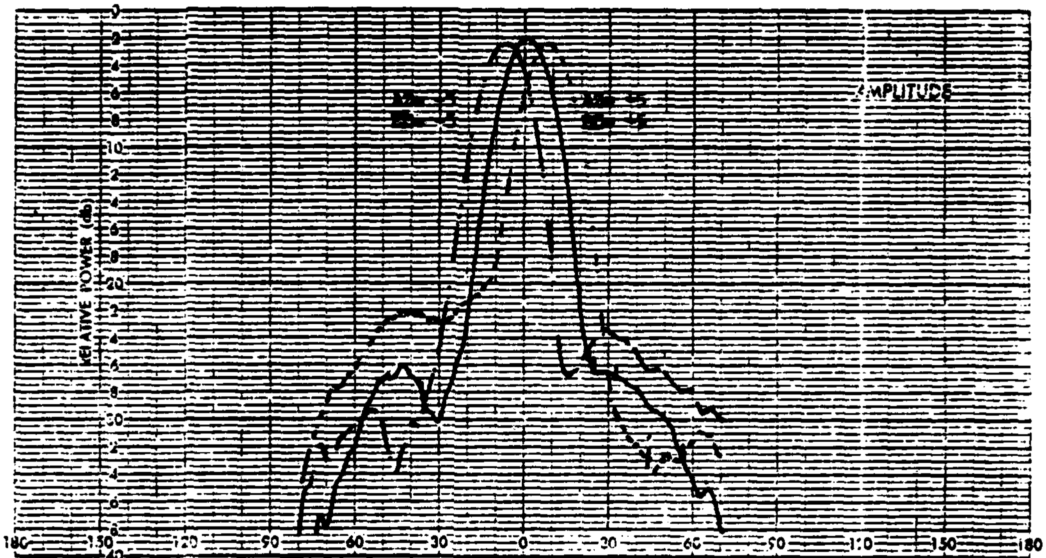
20° SCAN

0° AZIMUTH

HARRIS ELECTRONIC SYSTEMS DIVISION

ELEVATION SCAN ARRAY PATTERNS

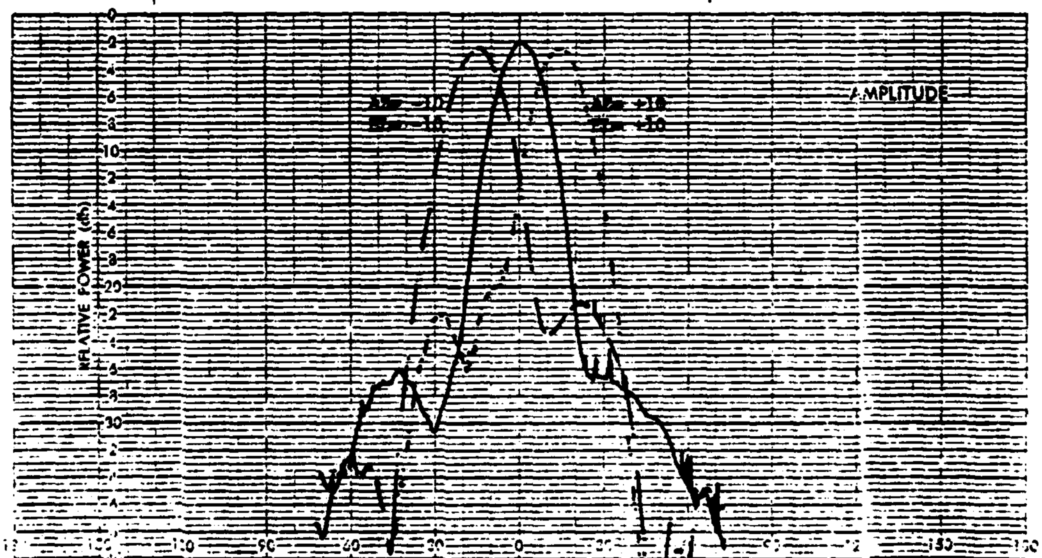
FIG. B-22



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED -45°

HARRIS ELECTRONIC SYSTEMS DIVISION

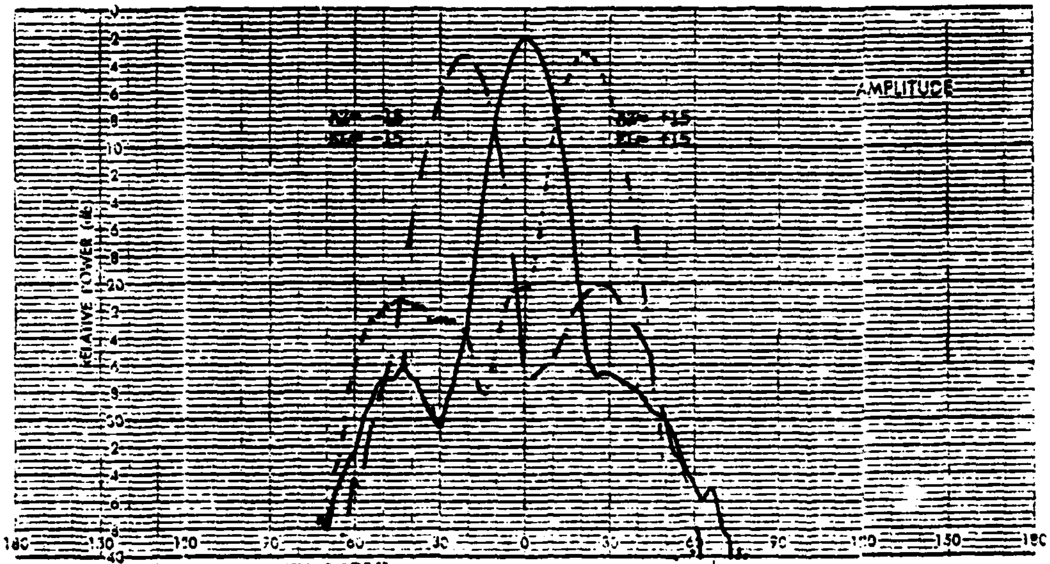


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED -45°

HARRIS ELECTRONIC SYSTEMS DIVISION

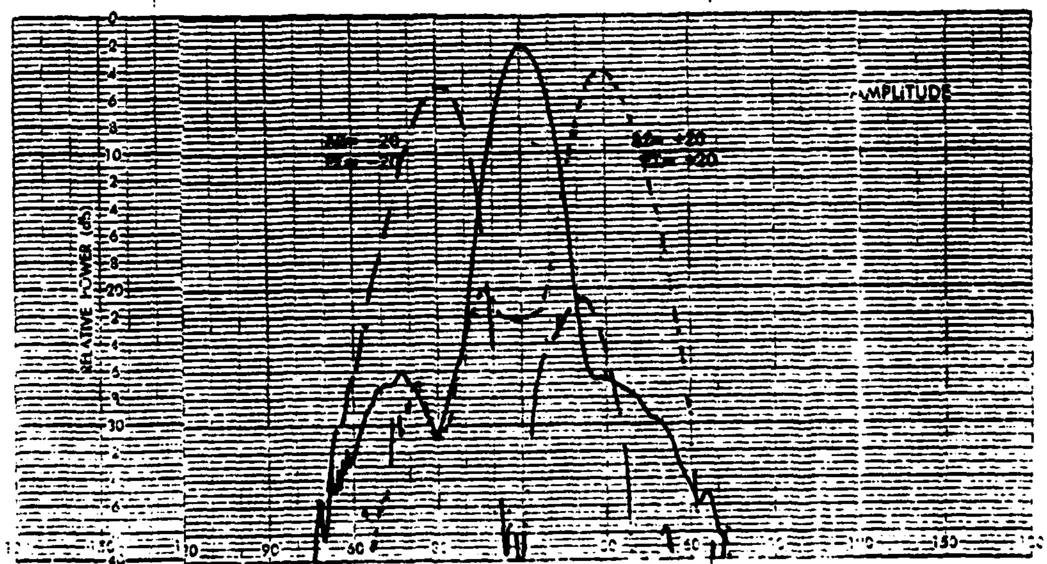
-45° SCAN PLANE ARRAY PATTERNS
FIG. B-23



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED
-45°

HARRIS
ELECTRONIC SYSTEMS DIVISION

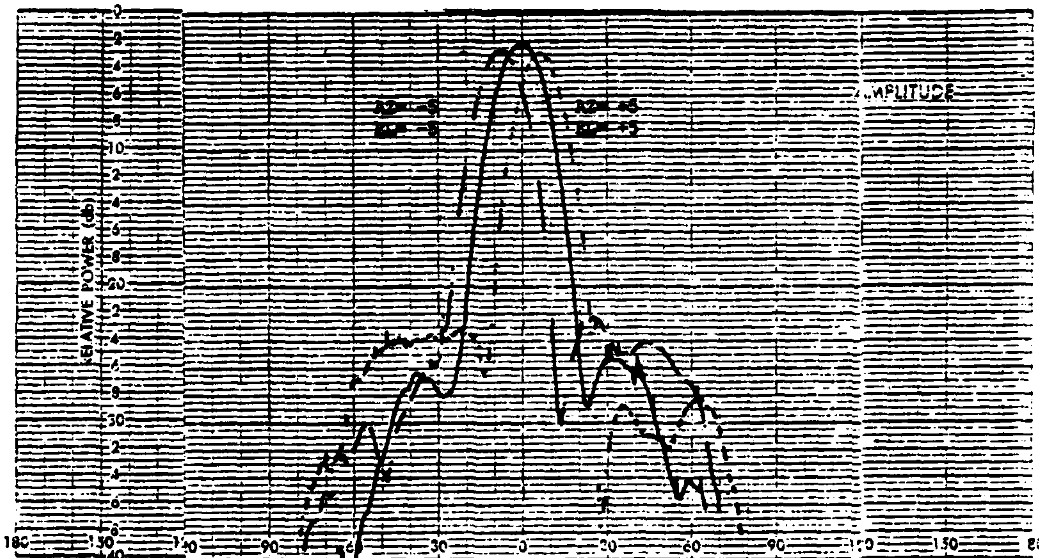


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED
-45°

HARRIS
ELECTRONIC SYSTEMS DIVISION

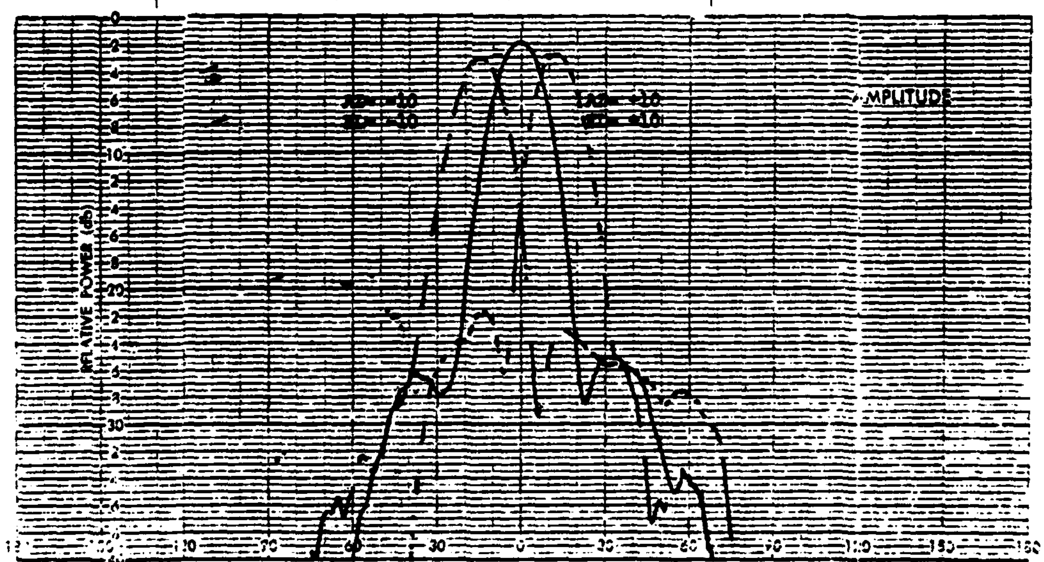
-45° SCAN PLANE ARRAY PATTERNS
FIG. B-24



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED -45°

HARRIS ELECTRONIC SYSTEMS DIVISION

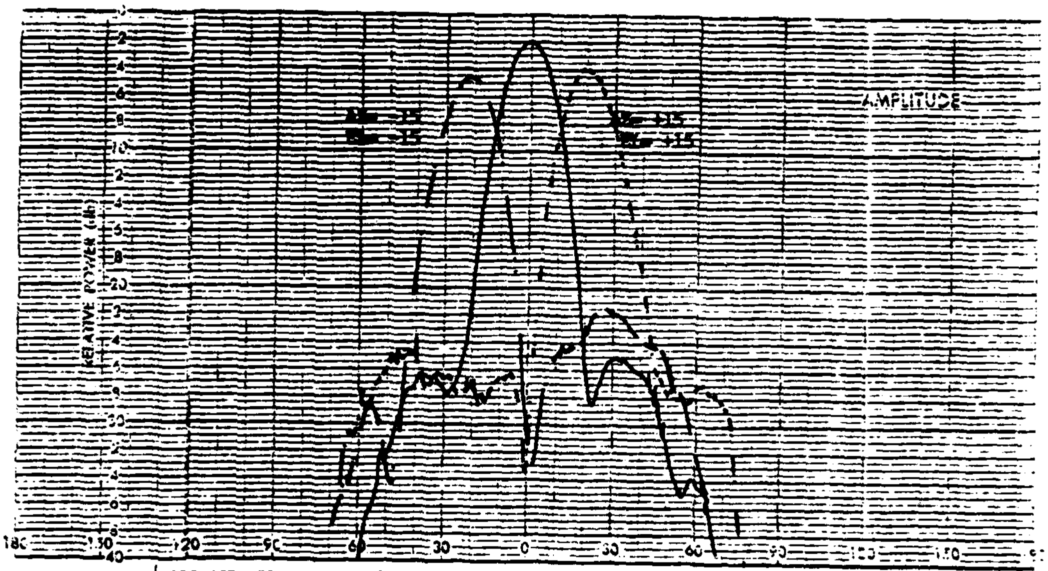


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED -45°

HARRIS ELECTRONIC SYSTEMS DIVISION

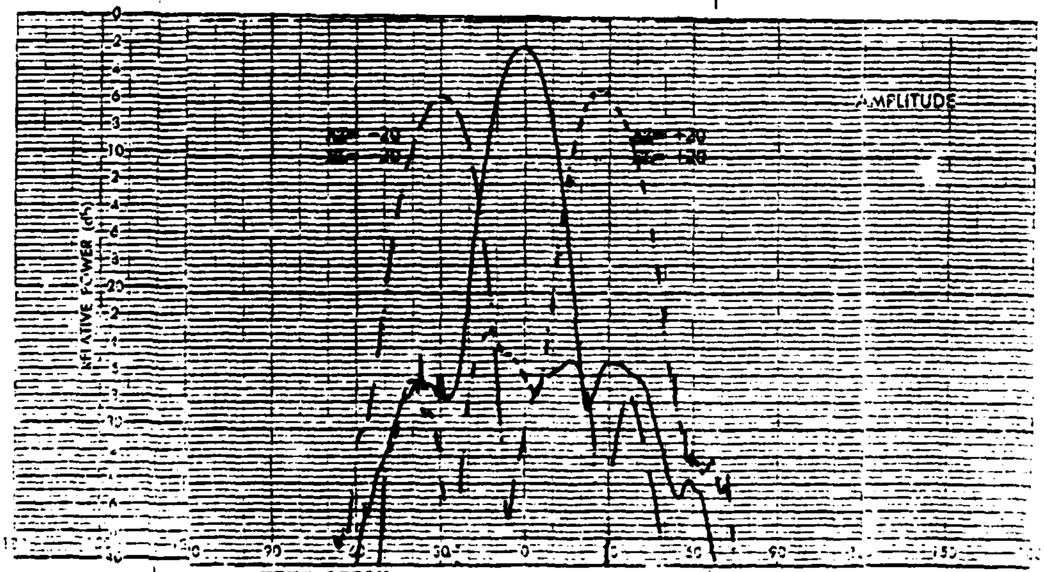
-45° SCAN PLANE ARRAY PATTERNS
FIG. B-25



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED -45°

HARRIS

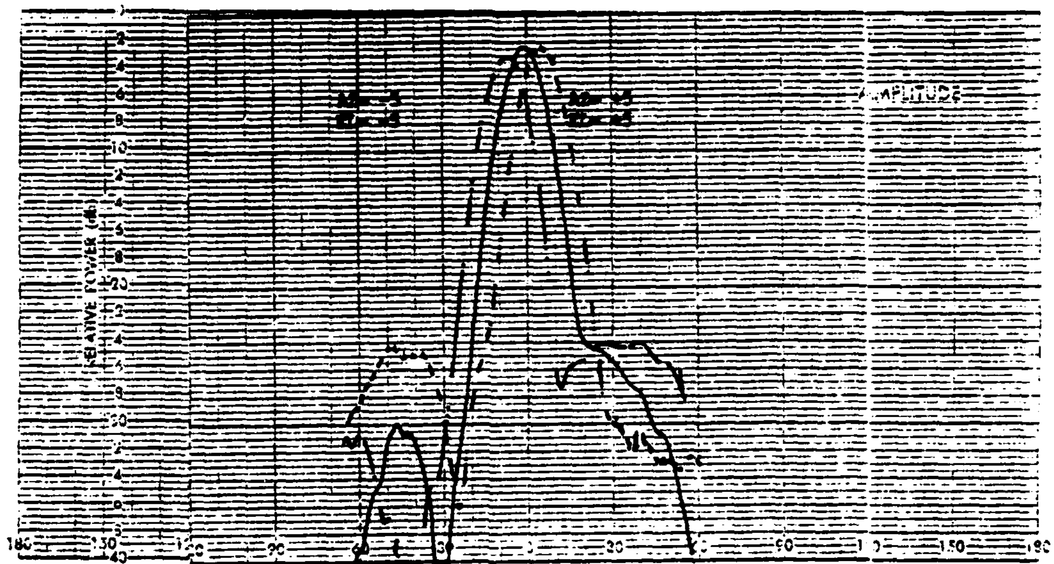


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED -45°

HARRIS

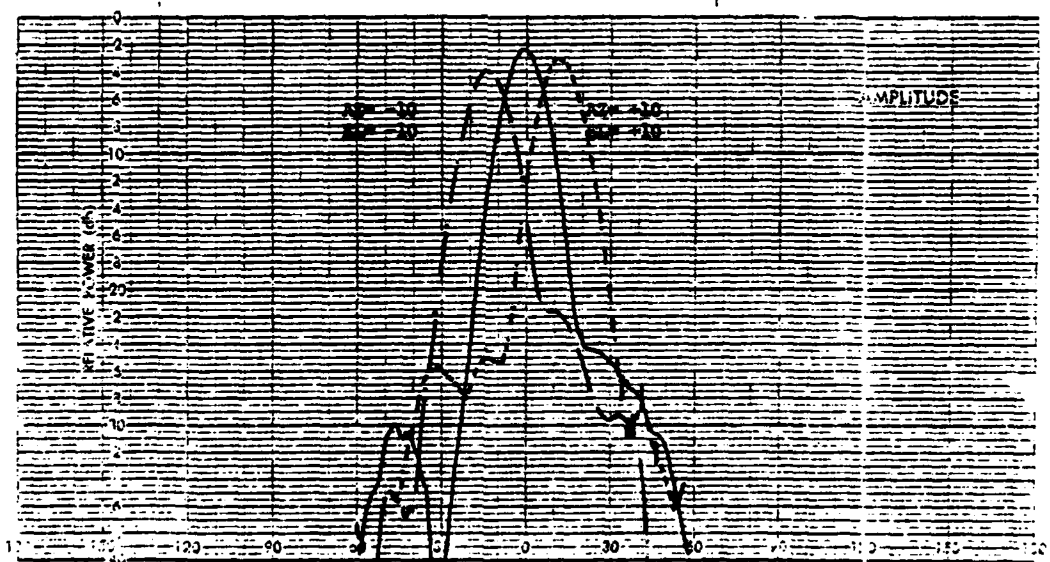
-45° SCAN PLANE ARRAY PATTERNS
FIG. B-26



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.7 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED -45°

HARRIS

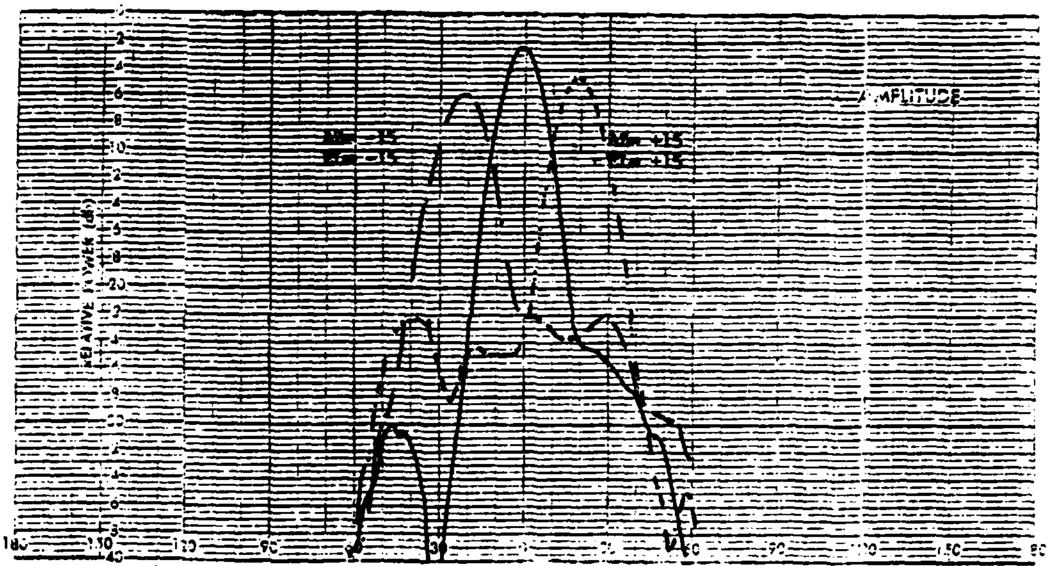


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.7 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED -45°

HARRIS

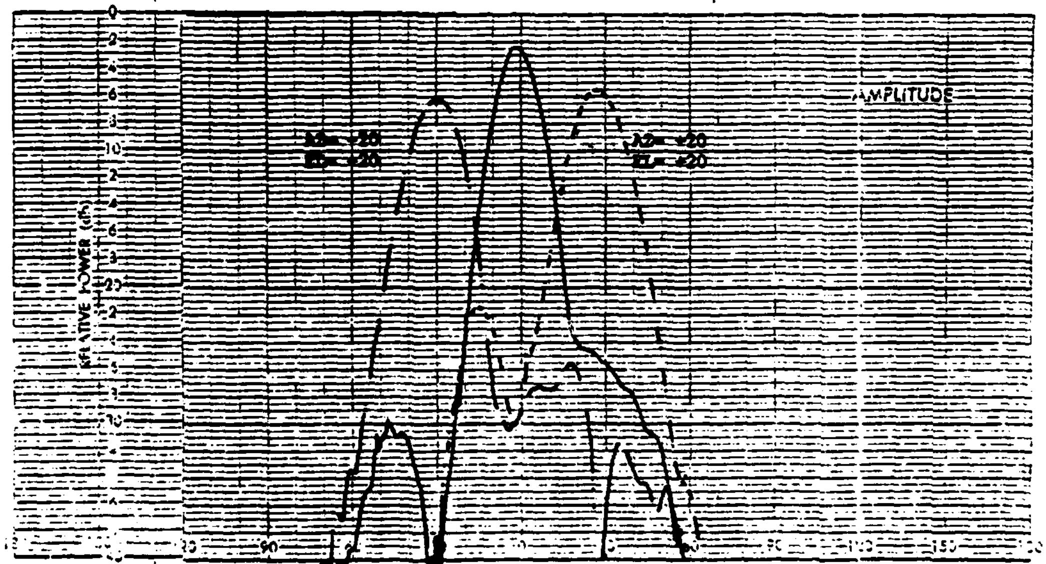
-45° SCAN PLANE ARRAY PATTERNS
FIG. B-27



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.7 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED -45°

HARRIS

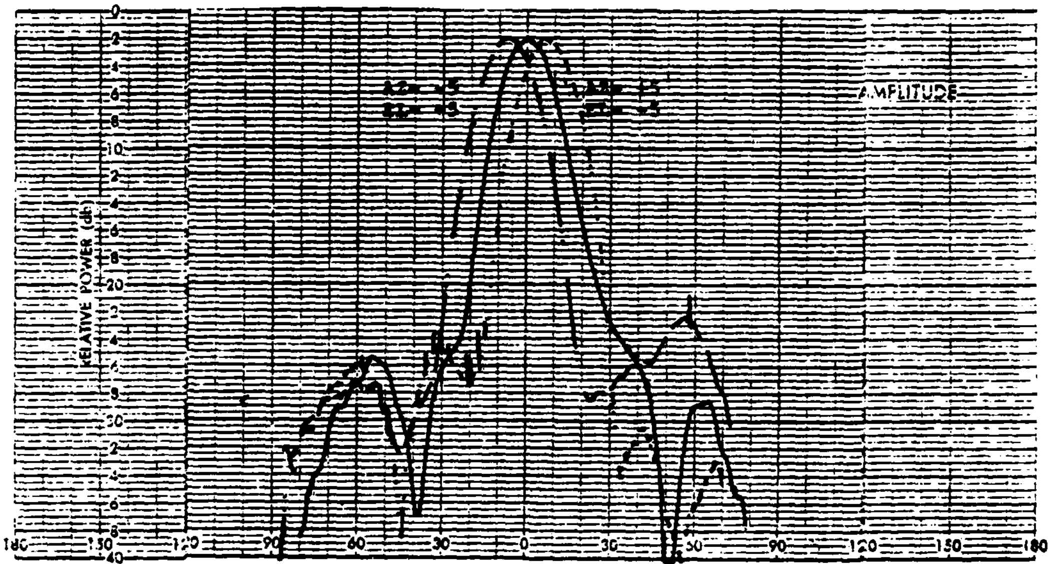


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.7 GHZ
PLANE -45° CUT, LCP
DATE 4/14/81

ARRAY ROLLED -45°

HARRIS

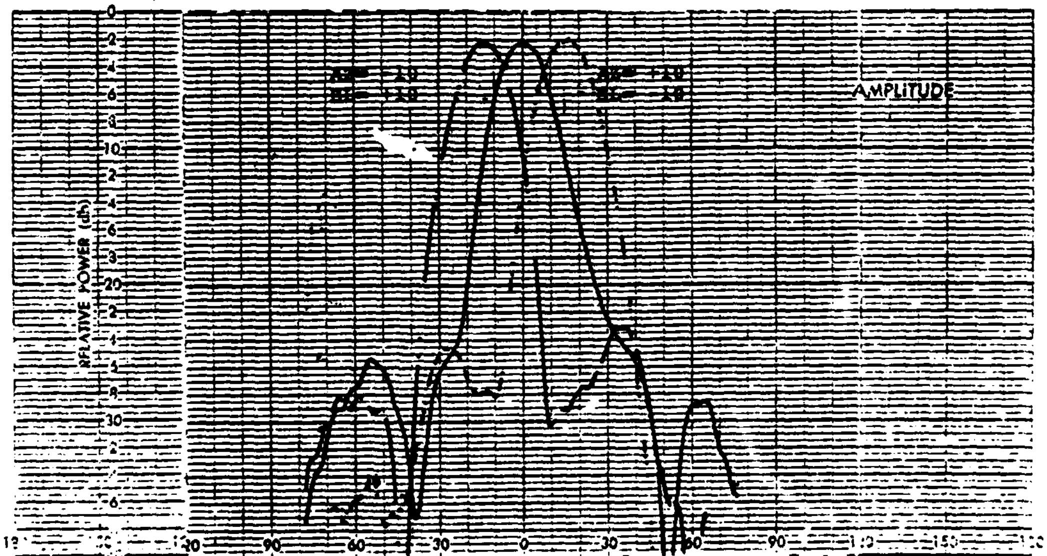
-45° SCAN PLANE ARRAY PATTERNS
FIG. B-28



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE +45° CUT, LCP
DATE 4/13/81

ARRAY ROLLED 45°

HARRIS ELECTRONIC SYSTEMS DIVISION

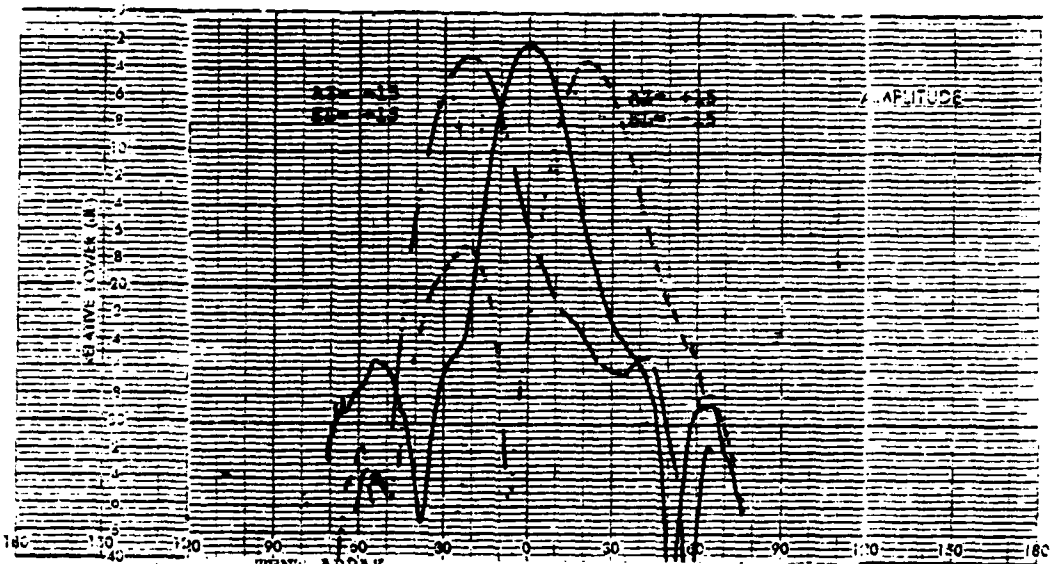


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE 45°-LCP-AZ CUT
DATE 4/13/81

ARRAY ROLLED 45°

HARRIS ELECTRONIC SYSTEMS DIVISION

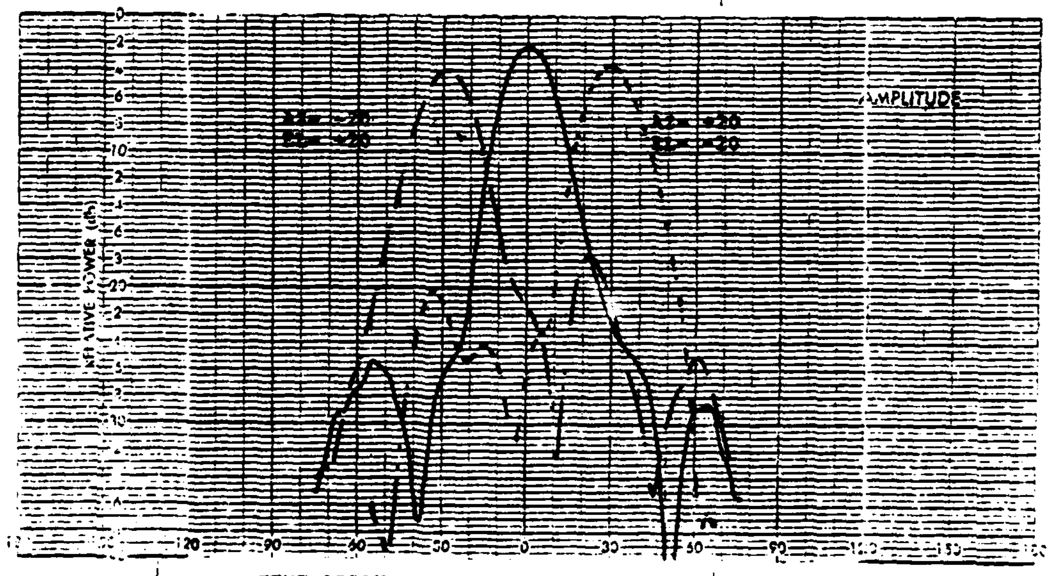
+45° SCAN PLANE ARRAY PATTERNS
FIG. B-29



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE AZ-LCP-AZ CUT
DATE 4/13/81

ARRAY ROLLED 45°

HARRIS ELECTRONIC SYSTEMS DIVISION

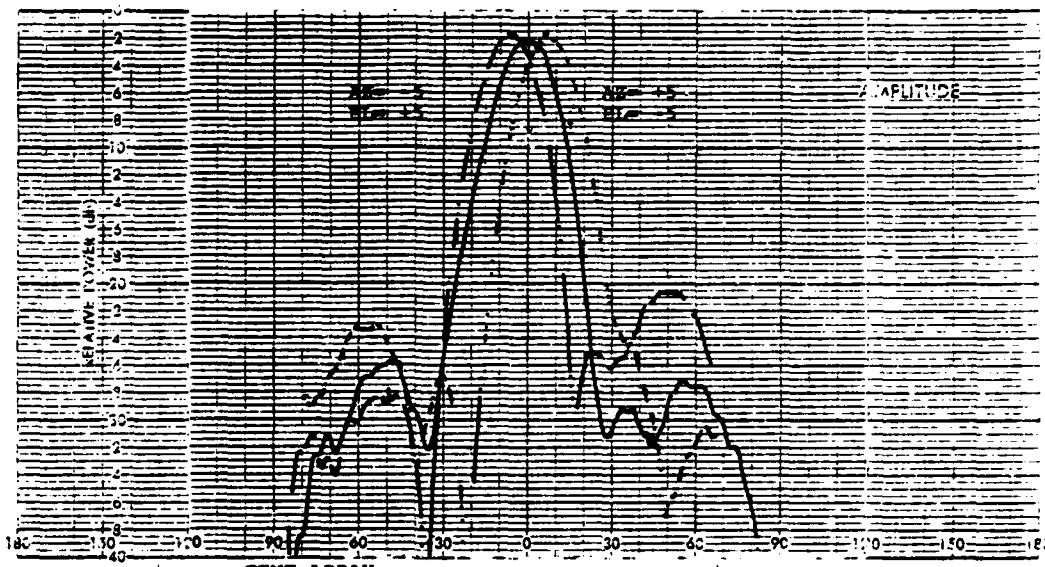


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.25 GHZ
PLANE 45°-LCP-AZ CUT
DATE 4/13/81

ARRAY ROLLED 45°

HARRIS ELECTRONIC SYSTEMS DIVISION

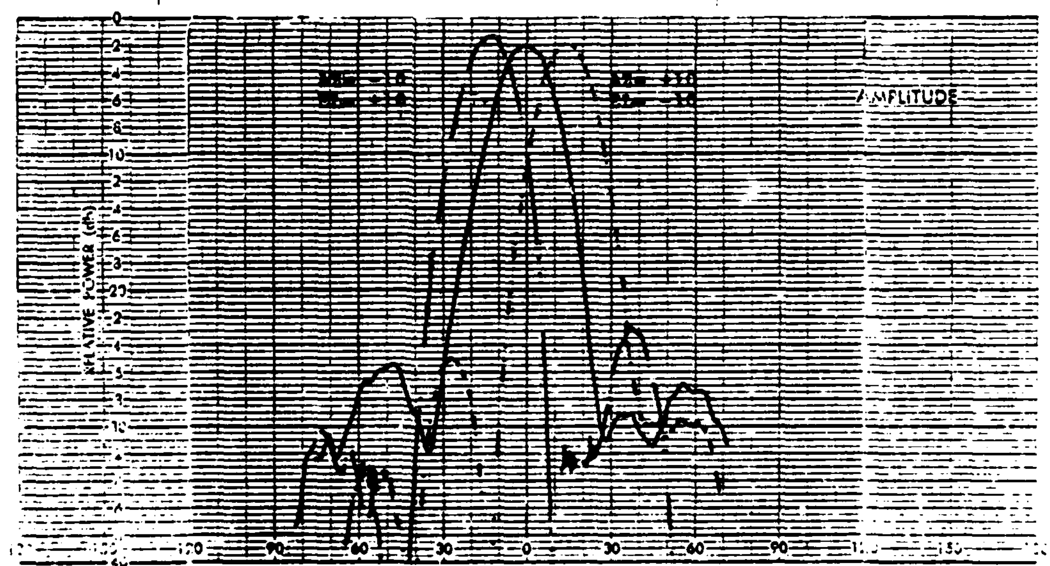
+45° SCAN PLANE ARRAY PATTERNS
FIG. B-30



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE +45° CUT, LCP
DATE 4/13/81

ARRAY ROLLED 45°

HARRIS



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE 45°-LCP-AZ CUT
DATE 4/13/81

ARRAY ROLLED 45°

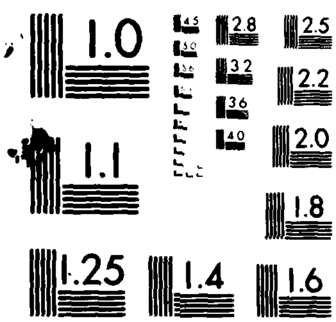
HARRIS

+45° SCAN PLANE ARRAY PATTERNS
FIG. B-31

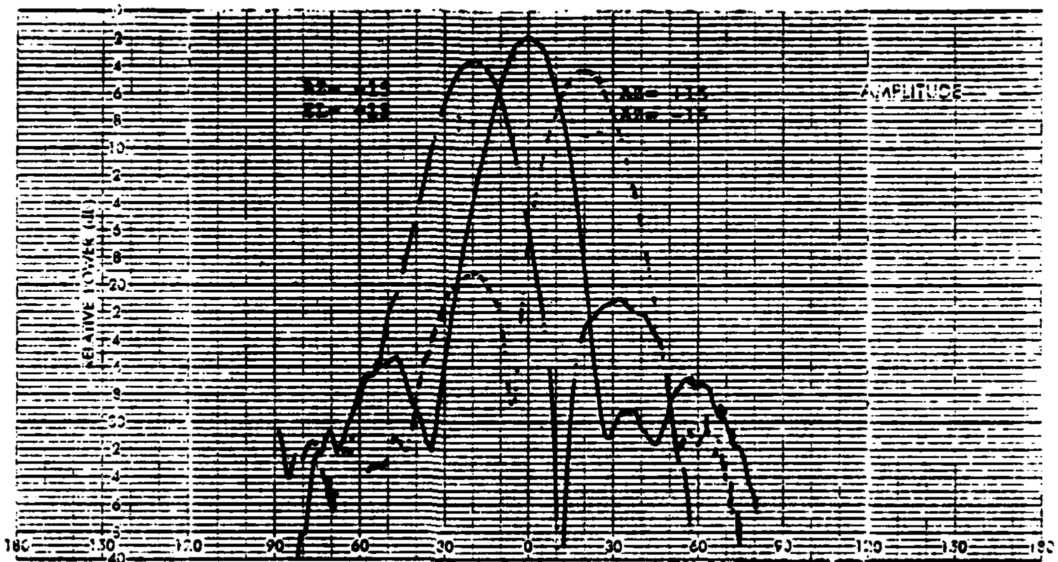
AD-A113 191 HARRIS CORP MELBOURNE FL GOVERNMENT COMMUNICATION SY--ETC F/G 20/14
TENT SHAPED PHASED ARRAY TESTS.(U)
JAN 82 C A CHUANG F19628-79-C-0173
UNCLASSIFIED RADC-TR-81-281 NL

2 · 2

END
DATE
FILMED
4 82
DTIC



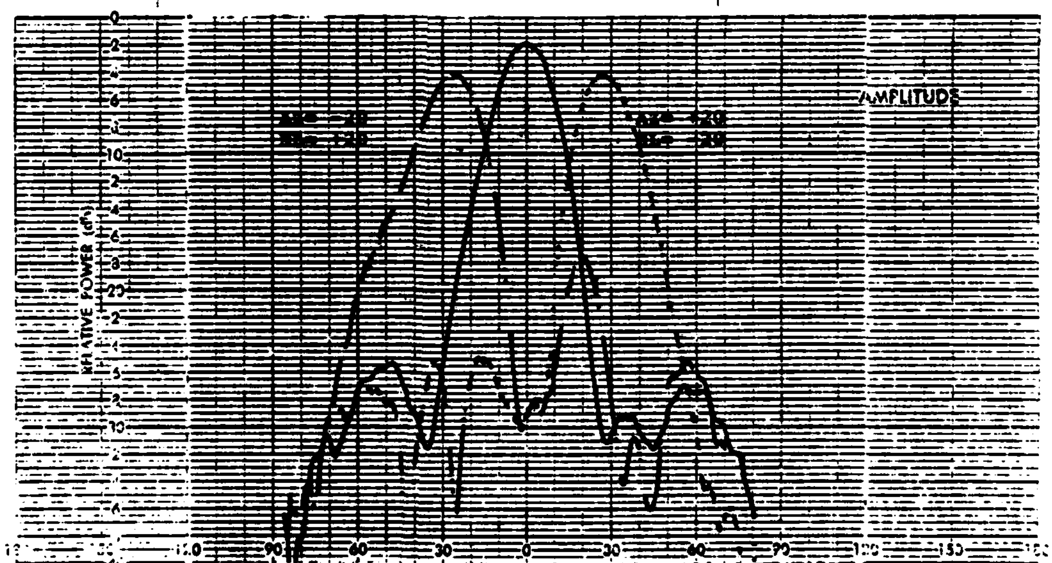
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE 45°-LCP-AZ CUT
DATE 4/13/81

ARRAY ROLLED 45°

HARRIS
ELECTRONIC SYSTEMS DIVISION

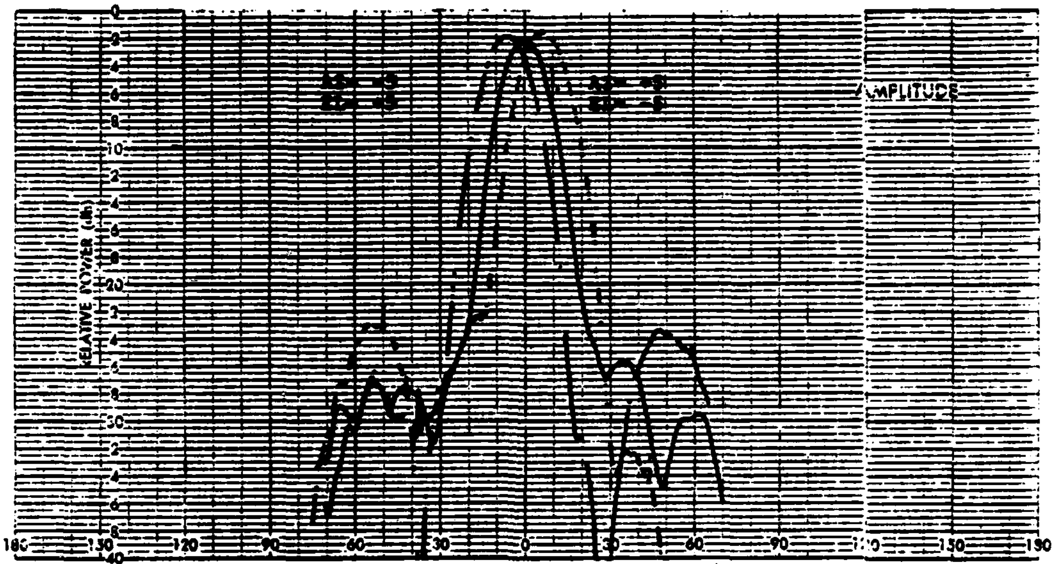


PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.5 GHZ
PLANE 45° LCP- AZ CUT
DATE 4/13/81

ARRAY ROLLED 45°

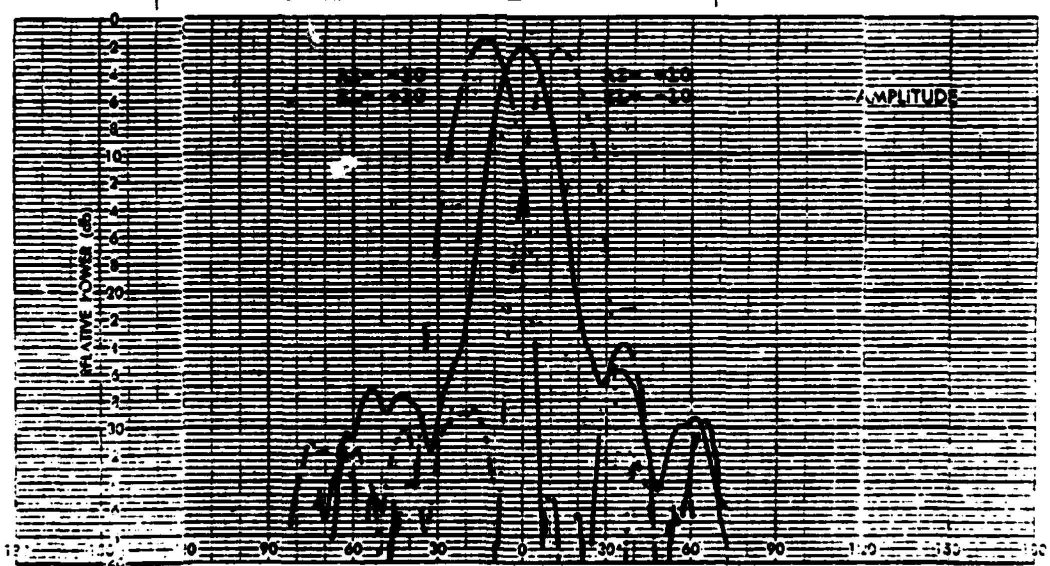
HARRIS
ELECTRONIC SYSTEMS DIVISION

+45° SCAN PLANE ARRAY PATTERNS
FIG. B-32



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.7 GHZ
PLANE +45° CUT, LCP — ARRAY ROLLED 45°
DATE 4/13/81

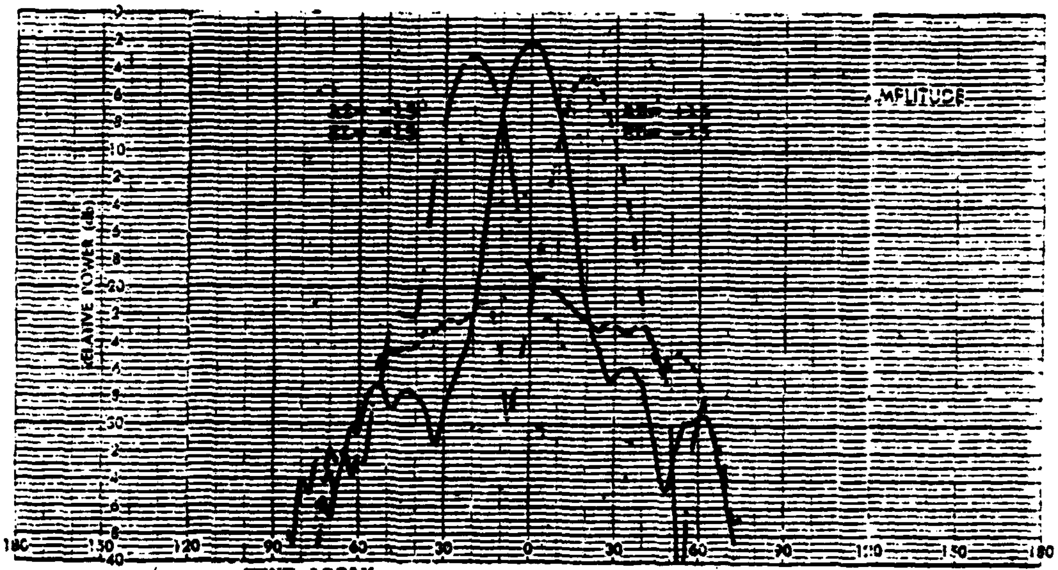
HARRIS
ELECTRONIC SYSTEMS DIVISION



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.7 GHZ
PLANE 45°-LCP-AZ CUT — ARRAY ROLLED 45°
DATE 4/13/81

HARRIS
ELECTRONIC SYSTEMS DIVISION

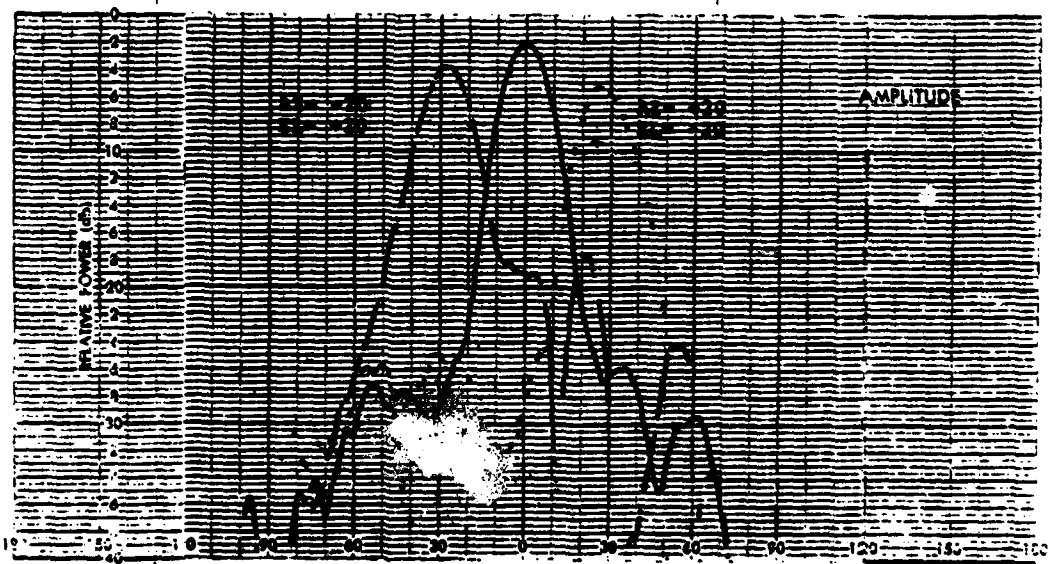
+45° SCAN PLANE ARRAY PATTERNS
FIG. B-33



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.7 GHZ
PLANE 45°-LCP-AZ CUT
DATE 4/13/81

ARRAY ROLLED 45°

HARRIS



PROJECT TENT ARRAY
MODEL BB 4X6 UNIT
FREQUENCY 7.7 GHZ
PLANE 45°-LCP-AZ CUT
DATE 4/13/81

ARRAY ROLLED 45°

HARRIS

+45° SCAN PLANE ARRAY PATTERNS
FIG. B-34